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PUBLICATION

Stratified-Drift Aquifers in the Susquehanna River Basin, New York

Prepared by

UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

BULLETIN 75

1982

NEW YORK STATE/DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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By

Robert D. MacNish and Allan D. Randall

U.S. Geological Survey

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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Albany, New York

1982

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(in pocket)

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CONVERSION FACTORS

The following factors may be used to convert the units of measurement in this report to the International System (SI) of units.

Multiply	by	To obtain
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.59	square kilometer
gallon	3.785	liter
gallon per minute	0.0631	liter per second
gallon per day	3.785	liter per day
cubic foot per second	28.32	liter per second
gallon per day per foot	12.42	liter per day per meter
gallon per day per square foot	0.041	meter per day
gallon per day per mile	2.35	liter per day per kilometer
gallon per day per square mile	1.46	liter per day per square kilometer
cubic foot per second per square mile	10.93	liter per second per square kilometer
micromho per centimeter	1.00	microsiemens per centimeter

Symbols used in the text of this report include:
°C, degree Celsius

STRATIFIED-DRIFT AQUIFERS IN THE SUSQUEHANNA RIVER BASIN, NEW YORK

By

Robert D. MacNish and Allan D. Randall

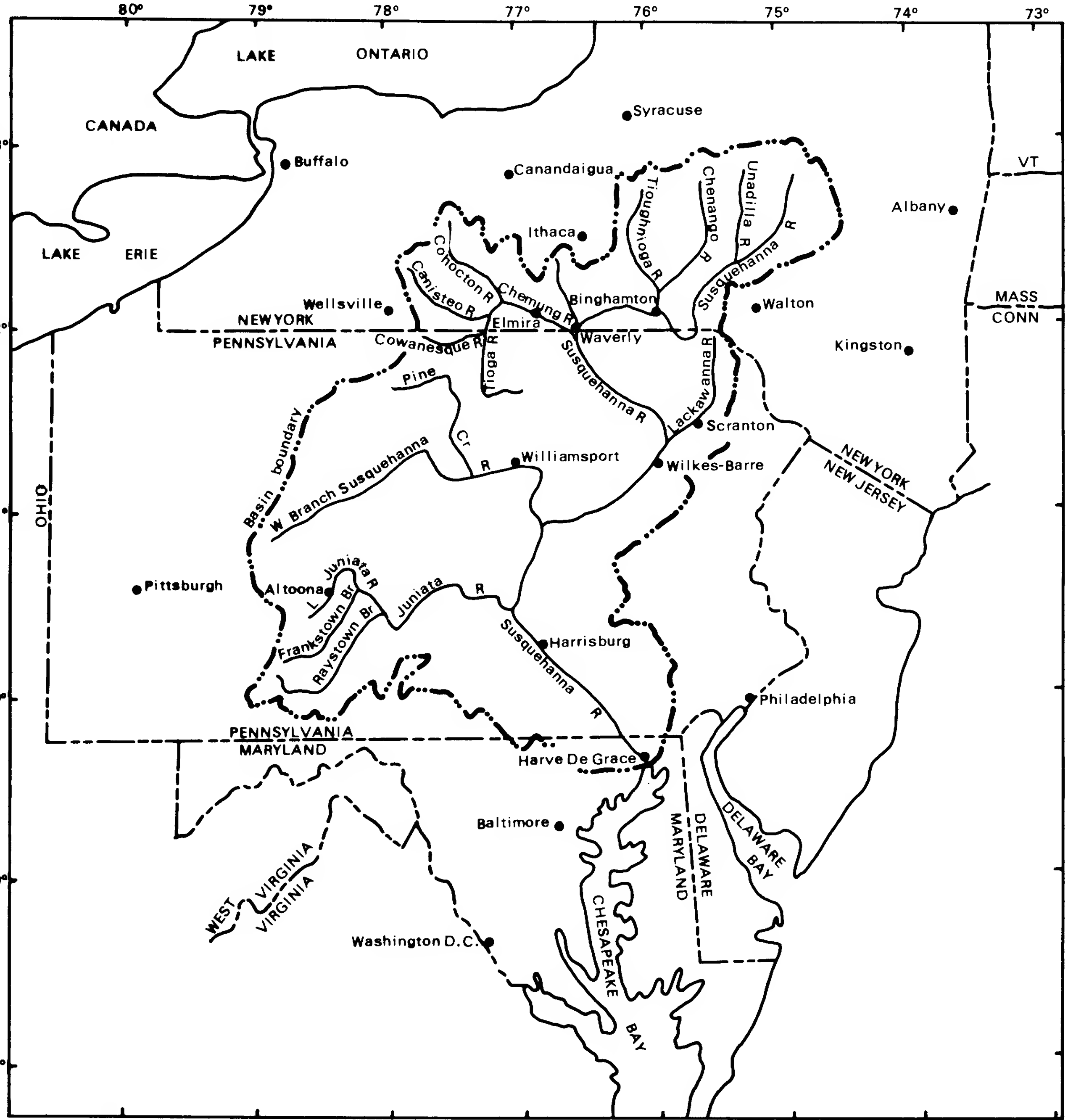
ABSTRACT

About 15 percent of the Susquehanna River basin is occupied by broad valleys that are floored with stratified glacial drift 70 to 500 feet thick. The stratified drift contains productive aquifers of sand or gravel in most localities; the estimated extent, depth, and water-storage capacity of 550 such aquifers are shown on maps and tables. A method is presented for estimating the yield of these aquifers by accounting for and combining the principal factors that control aquifer recharge. These factors include precipitation on surficial aquifers and adjacent hillsides, infiltration from small tributary streams crossing surficial aquifers, storage available in each aquifer, induced infiltration through the beds of major streams, and rates of flow in streams. The recharge rates and aquifer dimensions needed to estimate the yield of each aquifer are supplied, and the aquifers in one locality are evaluated as an example. Yields estimated by this method are appropriate for reconnaissance or preliminary planning. The method could be applied to stratified-drift aquifers in other basins.

INTRODUCTION

The Susquehanna River basin covers 6,100 square miles in south-central New York. Bedrock underlies the entire basin and can provide enough water for a single home at almost all locations. However, wells tapping the upper few hundred feet of bedrock rarely yield more than 50 gallons per minute. Till, a type of glacial drift that covers the bedrock on hills and in small valleys, is even less productive and in many places will not provide a dependable supply for even a single home. In contrast, the stratified drift in the large valleys contains highly productive aquifers; municipal and industrial wells tapping stratified drift commonly yield several hundred gallons per minute.

This report describes the stratified-drift aquifers of the basin, shows their location and extent, and presents a method for evaluating their potential yields. It is one of several reports based on studies made by the U.S. Geological Survey in cooperation with the New York State Department of Environmental Conservation to describe the occurrence of water in the Susquehanna River basin in New York.



Base from Susquehanna River Basin Commission, 1973

Figure 1A.--Location and geographic features of Susquehanna River basin. Area described in this report is north of New York-Pennsylvania boundary.

SUSQUEHANNA RIVER BASIN IN NEW YORK

Location and Major Geographic Features

The Susquehanna River rises in central New York, flows generally southwestward to Waverly, then generally southward across Pennsylvania and through the narrowest part of eastern Maryland to empty into Chesapeake Bay (fig. 1A). Five major tributaries--the Unadilla, Tioughnioga, Chenango, Canisteo, and Cohocton-Chemung Rivers--flow into the main stem in New York. Another major tributary, the Tioga River, flows northward out of Pennsylvania and joins the Canisteo River, thus adding its flow to the New York part of the system.

Within New York, the Susquehanna River basin extends 170 miles from its western border in Allegheny County to its eastern border in Schoharie County, and 70 miles from Oneida County southward to Pennsylvania. Although only one county (Tioga) lies entirely within the basin, 18 of New York's 62 counties contribute flow to the system (fig. 1B).

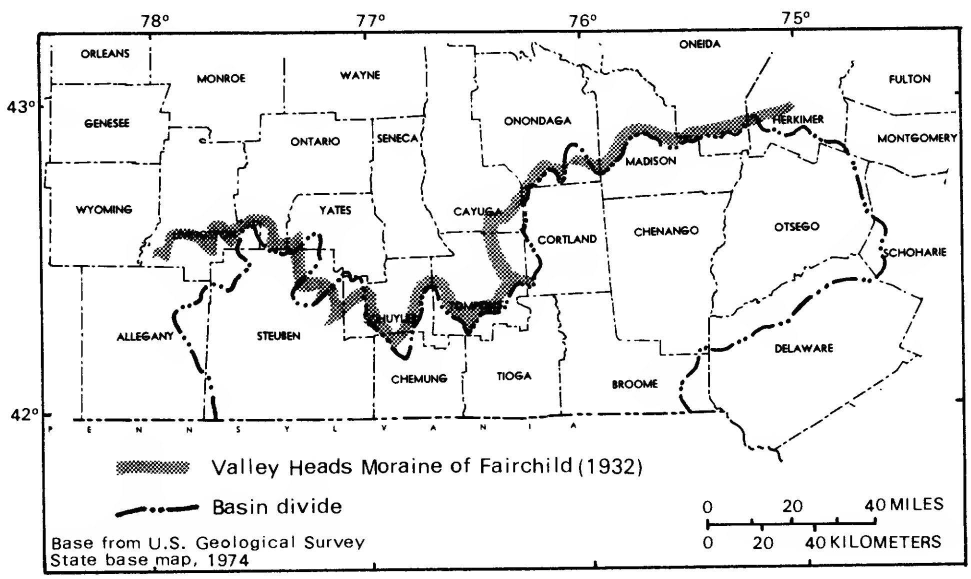


Figure 1B.--Location of New York counties in Susquehanna River basin.

Geology and Physiography

Beginning about 500 million years ago and continuing for 250 million years thereafter, a shallow sea covered a large part of what is now the Eastern United States. Near the southeast corner of the area described in this report (figs. 1A and 1B), a large river emptied into the sea and gradually built a delta across the entire report area. As sediments accumulated, their weight compressed underlying limey muds and clays into limestones and shales. Ground water percolating through the sediments dissolved minerals and redeposited them as cements, thereby turning silts and sands into siltstones and sandstones, and sand and gravel mixtures into conglomerates. Subsequent stresses within the Earth caused uplift, extensive folding, and shattering of

these layered sediments in large areas south and east of the report area, but most of New York was distant enough from these stresses that it experienced only gentle flexures and minor fissures and cracks. During and after these periods of uplift, rivers eroded the land down to a gently undulating plain (Cressy, 1966) that must have looked similar to the present Great Plains in the Midwestern States.

About 65 million years ago, when renewed uplift created the Appalachian Plateau in central New York and areas to the south, rejuvenated streams cut deep, narrow valleys into the gently undulating land surface. Some of these valleys are preserved in unglaciated parts of the Susquehanna River basin south of New York.

During the Ice Age, which began about a million years ago, continental glaciers flowed southward from north-central Canada and covered the New York part of the Susquehanna River basin at least once, perhaps several times. As the ice flowed over the area, it greatly deepened and widened most valleys and, in so doing, reversed the direction of the slope of some of the valleys so that some postglacial rivers flowed in a direction opposite that of the preglacial rivers. With the final melting of the ice a little more than 10,000 years ago, the deep valleys became partly filled with tens or hundreds of feet of sediment, and the land surface took on its present configuration.

The geology and physiography of the present Susquehanna River basin in New York reflects all the geologic development described above. The basin is underlain by nearly horizontal bedrock units, with sandstones and conglomerates in the southeast grading into interbedded siltstones and shales in the central and western parts, and the siltstones and shales in turn grading into limestones and shales along the northern rim of the basin. Deep, broad valleys that were cut into the bedrock are partly filled by fine lake sediments, sands, and gravels deposited by meltwater from the receding ice sheets, and a mantle of unsorted debris known as till is spread across the hills. The flat tops of the broad hills between the valleys are remnants of the Appalachian Plateau.

GROUND WATER IN THE SUSQUEHANNA RIVER BASIN

Data Available

Records of wells, springs, and geologic test borings in the Susquehanna River basin have been collected periodically by the U.S. Geological Survey from a variety of sources, including home owners, well drillers, consulting engineers, and public or industrial water-system managers. From 1965 through 1968, the Survey collected nearly 2,000 new or revised records of wells and 725 records of test borings. Most of these records were from the large valleys, where ground-water studies were concentrated to reveal as much as possible about the productive stratified-drift aquifers, especially aquifers in densely populated valleys, where the need for information on ground water is greatest.

The distribution of wells from which records were obtained is shown in figure 2; the completeness of those records is shown in figure 3. All data

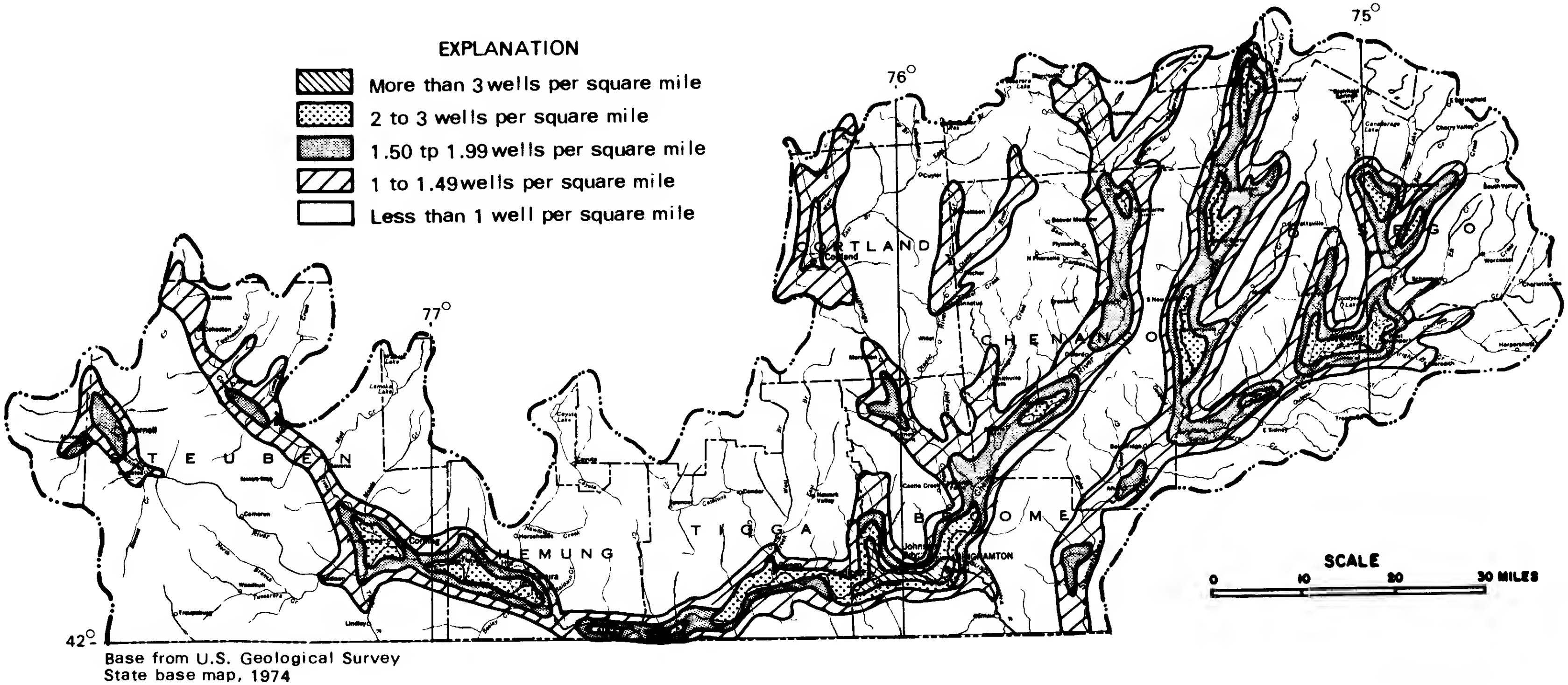


Figure 2.--Density of wells and test borings from which data were collected from 1965 through 1968.

except geologic logs are stored on magnetic tape as part of the Geological Survey's national ground-water-data storage system. Complete records of all wells and test borings, including geologic logs, are published in a separate report (Randall, 1972), which is accompanied by maps showing locations of the wells and test borings and includes references to several published and unpublished sources of records collected in previous studies.

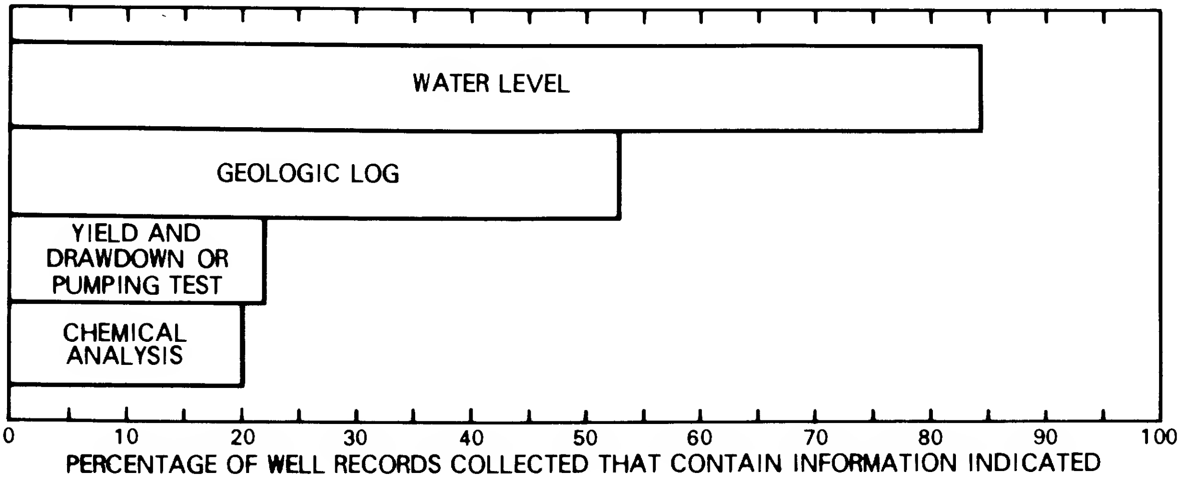


Figure 3.--Percentage of wells from which water-level data, geologic logs, pumping-test records, and chemical analyses were obtained.

Description of Aquifers

The distribution of ground water in the Susquehanna River basin can be conveniently discussed in terms of the geologic environments in which the water occurs. Roughly 85 percent of the basin is a bedrock upland dissected by narrow valleys and veneered by till; the remaining 15 percent consists of broad valleys floored by stratified sediments.

Till and bedrock aquifers

Many farms and homes in upland areas obtain water from till or bedrock. Most wells tapping the till are dug wells less than 25 feet deep and about 3 feet in diameter. These wells generally yield less than 0.5 gallons per minute, but their large diameter provides sufficient water storage to allow intermittent, short-term withdrawals at rates that exceed well yields. Drilled wells could probably obtain 20 to 50 gallons per minute at many locations by penetrating 300 feet or more of bedrock, although some deep wells yield very little water. The average reported yield of wells tapping bedrock is only about 8 gallons per minute (Wetterhall, 1959) because most are domestic wells in which drilling was stopped as soon as the owner's needs were met. Yields exceeding 100 gallons per minute are reported from a few of the wells tapping bedrock in major valleys, but some of these produce salty water,

and some, especially those reported to penetrate less than 10 feet of bedrock, may actually obtain water that enters the bedrock from stratified drift by leakage where the casing rests upon bedrock or through shallow seams in the bedrock.

Chemical quality of water in the till and bedrock is generally satisfactory for household use. Springs and dug wells yield water that is relatively soft and low in most dissolved constituents. The quality of shallow ground water in till and bedrock probably closely resembles that of upland streams at very low flow. Regional variation in specific conductance of upland streams at very low flow was described by Ku and others (1975, fig. 23), who found values in the northeastern and northwestern parts of the Susquehanna River basin in New York to be much higher than in areas to the south. Water from the limestone-shale bedrock in the northeastern part of the basin is generally high in hardness and locally high in sulfate, whereas water from the sandstone-siltstone-shale bedrock underlying the rest of the basin is generally moderate in hardness, with occasional excessive iron. The smell of hydrogen sulfide gas is common in water from the bedrock, particularly in valleys, and all water below the upper few hundred feet is salty throughout the basin.

Stratified-drift aquifers

Yields of wells tapping stratified sediments in the major valleys are much larger than yields of wells tapping till or bedrock in the upland. Municipal and industrial wells in the valleys yield more than 400 gallons per minute on the average; most have screens and have been developed to produce close to the maximum potential yield of the stratified drift at the specific site. Even domestic and farm wells, most of which lack screens and are designed to meet only small demands, obtain an average of 34 gallons per minute from the stratified drift. The variation in yield of wells tapping various types of stratified-drift aquifers is shown in table 1.

To facilitate description of the stratified-drift aquifers, the valleys of the Susquehanna River basin are grouped in this report into seven classes on the basis of sediment type and arrangement. In many places, the shape of the valley floor and walls indicates the type and arrangement of sediments below the surface; this basis was used to classify valley reaches where subsurface data are sparse. Figures 4 through 10 depict the typical subsurface geometry of the seven valley classes and the location of each class within the basin. Figures 4 and 5 represent moderately narrow valleys, which typically contain 10 to 40 feet of saturated sand and gravel overlying till or bedrock; figures 6-10 represent broad valleys.

Depth to bedrock below stream grade generally ranges from 250 to 500 feet in broad valleys northeast of Binghamton. West of Binghamton, depths of 70 to 200 feet are typical, although some northeast-southwest-trending valleys contain more than 250 feet of stratified drift. Not all stratified drift in broad valleys is aquifer material. In general, the greater the depth to bedrock, the greater the thickness of clay, silt, and fine sand; total thickness of water-yielding gravel and coarse sand rarely exceeds 150 feet regardless of the depth to bedrock and may be as little as 10 feet in some localities.

Table 1.--Variation in specific capacity and yield of wells in stratified-drift aquifers in valleys of the Susquehanna River basin in New York

[Modified from Hollyday, 1969]

	Aquifer position and thickness 1/						
	Surficial; top 0 to (rarely) 50 feet below water table			Buried beneath 50 to 200 feet of lacustrine deposits			Buried beneath >200 feet lacustrine deposits
Summary of yield data analyzed 2/	<10 feet thick	10-40 feet thick	>40 feet thick	<10 feet thick	10-40 feet thick	>40 feet thick	Any thickness
Specific capacity (gallons per minute per foot of drawdown) equaled or exceeded by the following percentages of wells:							
75 percent	4.4	22	34	2.3	13	19	0.67
50 percent	12	45	82	11	32	29	3.5
25 percent	33	94	200	60	82	44	22
Number of wells used for specific-capacity frequency-distribution analysis 3/	11	70	38	11	33	26	9
Potential yield expected to be equaled or exceeded by the following percentages of wells 4/							
75 percent (poor yield)							
Gallons per minute	66	550	1,500	120	520	1,200	110
Million gallons per day	.095	.79	2.2	.17	.75	1.7	.16
50 percent (medium yield)							
Gallons per minute	180	1,100	3,700	550	1,300	1,900	600
Million gallons per day	.26	1.6	5.3	.79	1.9	2.7	.86
25 percent (good yield)							
Gallons per minute	500	2,400	9,000	3,000	3,300	2,900	3,700
Million gallons per day	.72	3.5	13	4.3	4.8	4.2	5.3

1/ Many categories of position and thickness correspond to map units on plate 1; however, some subdivisions of buried aquifers differ.

2/ Values taken from a log-normal frequency distribution of reported data, adjusted to 180 days continuous pumping.

3/ About 2 percent of wells for which specific capacity data were available produced less than 10 gallons per minute, probably because of limitations in well design, and were excluded from analysis. The several exploratory wells drilled before selection of some well sites were not considered.

4/ Calculated from specific-capacity data, assuming drawdown to a depth halfway between static water level and typical well depth. For details see Hollyday (1969). The terms "poor," "medium," and "good" were applied by Hollyday as convenient labels.

During the waning stages of glaciation, tongues of ice flowed down the broad valleys, and a lake commonly extended from the end of each ice tongue to a barrier of previously deposited sediment further downvalley. Coarse sediment carried by ice-margin streams was deposited in the lakes as deltas. Where the rates of ice flow and ice wastage were nearly balanced so that the end of the ice tongue remained at the same point for a time, the deltas spread across the width of the valley and coalesced to form a large mass of mostly coarse, permeable material often termed a recessional moraine (fig. 6). Where the rate of ice wastage slightly exceeded the rate of ice flow, the deltas built up to lake surface but were unable to spread across the valley; these deltas now form terraces on one or both sides of the valley, well above the modern flood plain (fig. 7). Where the ice tongues retreated rapidly, there was not time for coarse sediment to build up to lake surface, but a thin layer was deposited at the mouths of subglacial meltwater streams and tributary valleys (fig. 8). In all these broad valleys (figs. 6-8), most of the fine sediment was carried in suspension downvalley to less turbulent parts of the lake, where it mantled previously deposited basal gravels.

In many relatively shallow valleys, the ends of the ice tongues often became too thin to flow; sediment was deposited in smaller lakes and streambeds that formed atop and against the motionless ice. The result is a heterogeneous but predominantly coarse and permeable deposit (fig. 9). In broad valleys along the northern basin divide, ice tongues repeatedly readvanced into large proglacial lakes and produced thick accumulations of interbedded till and fine-grained lake sediment with only minor amounts of sand and gravel (fig. 10); these masses are collectively known as the Valley Heads moraine (fig. 1B and Fairchild, 1932).

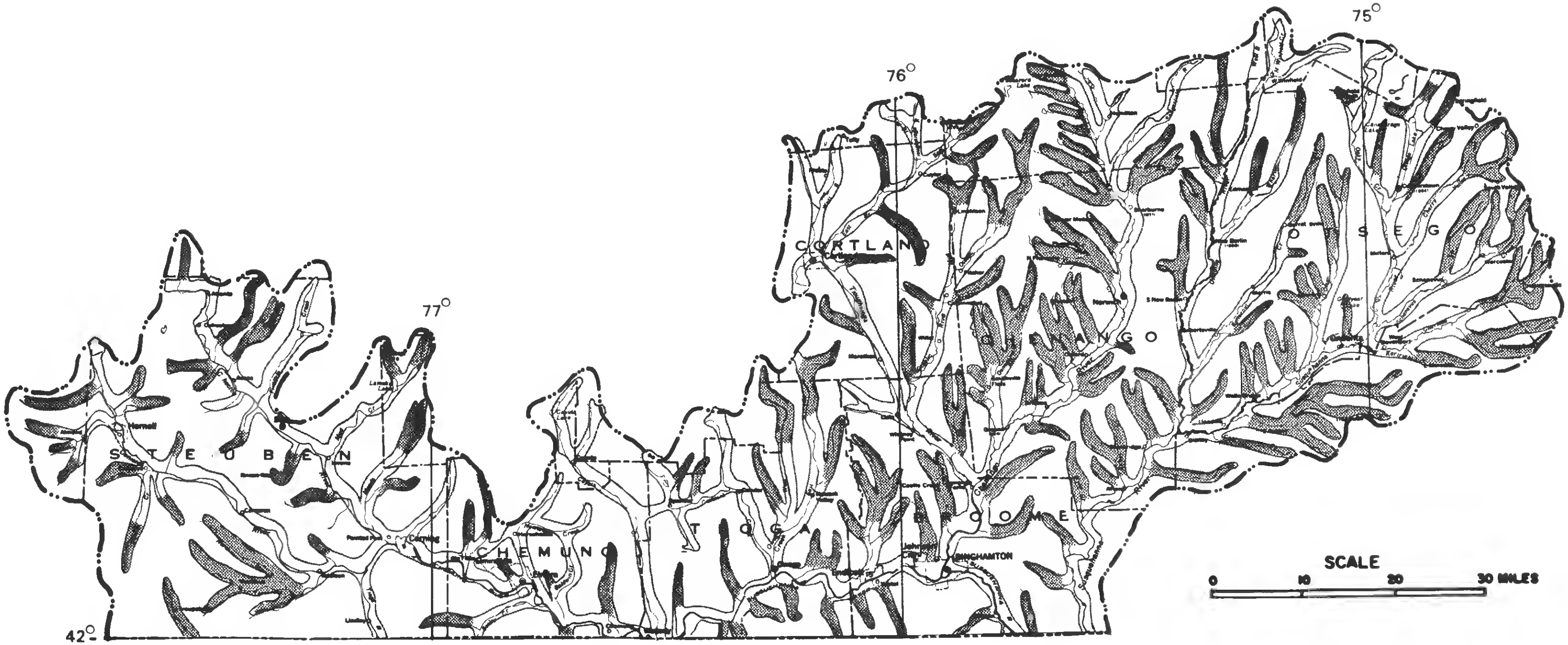
Figures 4 to 10 indicate that the stratified-drift aquifers in the valleys of the Susquehanna basin are highly varied in detail. However, some generalizations may be made:

1. Sand and gravels are commonly present at or near land surface in all classes of valleys. In some places these near-surface materials are thin or largely above the water table, but elsewhere they form the best aquifers in the basin because they are highly permeable and generally in hydraulic contact with streams from which water can infiltrate to sustain well yields.

2. In the broader valleys, basal sand and gravel aquifers may be even more widespread than surficial aquifers. However, they may also be less permeable and generally yield only moderate quantities of water. The water is commonly of inferior chemical quality, widely characterized by high iron, sulfate, or hardness and in some places by high chloride.

3. Locally, most commonly along the sides of the valleys, the entire thickness of stratified glacial drift is sand and gravel. Such locations may be thought of as unusually thick surficial aquifers that are promising for large well yields.

These generalizations were used in preparing the quantitative description of aquifer properties on pages 24-32.



Base from U.S. Geological Survey
State base map, 1974

Figure 4A.--Index map showing location of valleys typified in figure 4B.

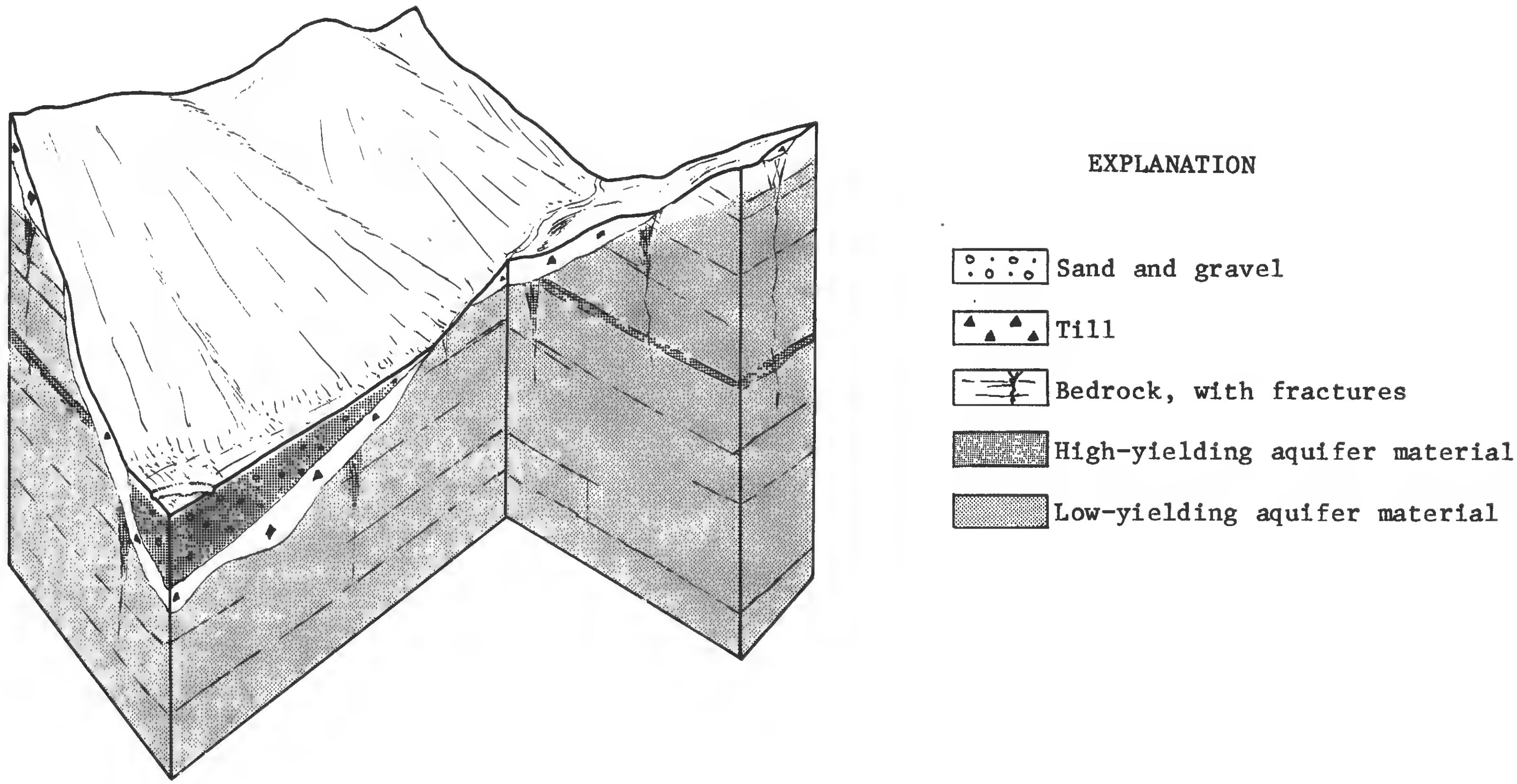


Figure 4B.--Geology and hydrology typical of most small tributary valleys. Valley floors a few hundred feet wide are underlain by approximately 10 feet of coarse alluvium deposited by the present stream; glacial meltwater deposits are absent. Most of these tributary valleys drain less than 30 square miles.

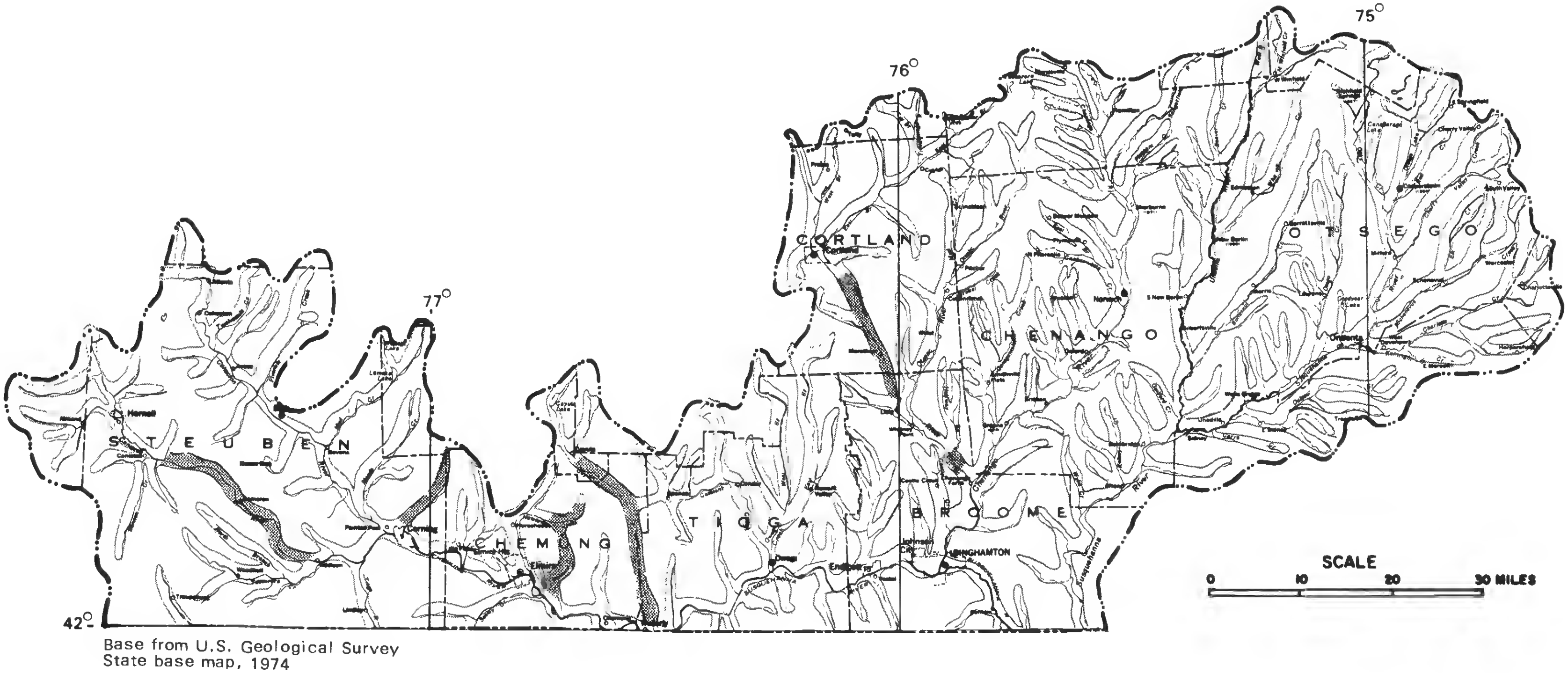


Figure 5A.--Index map showing location of valleys typified in figure 5B.

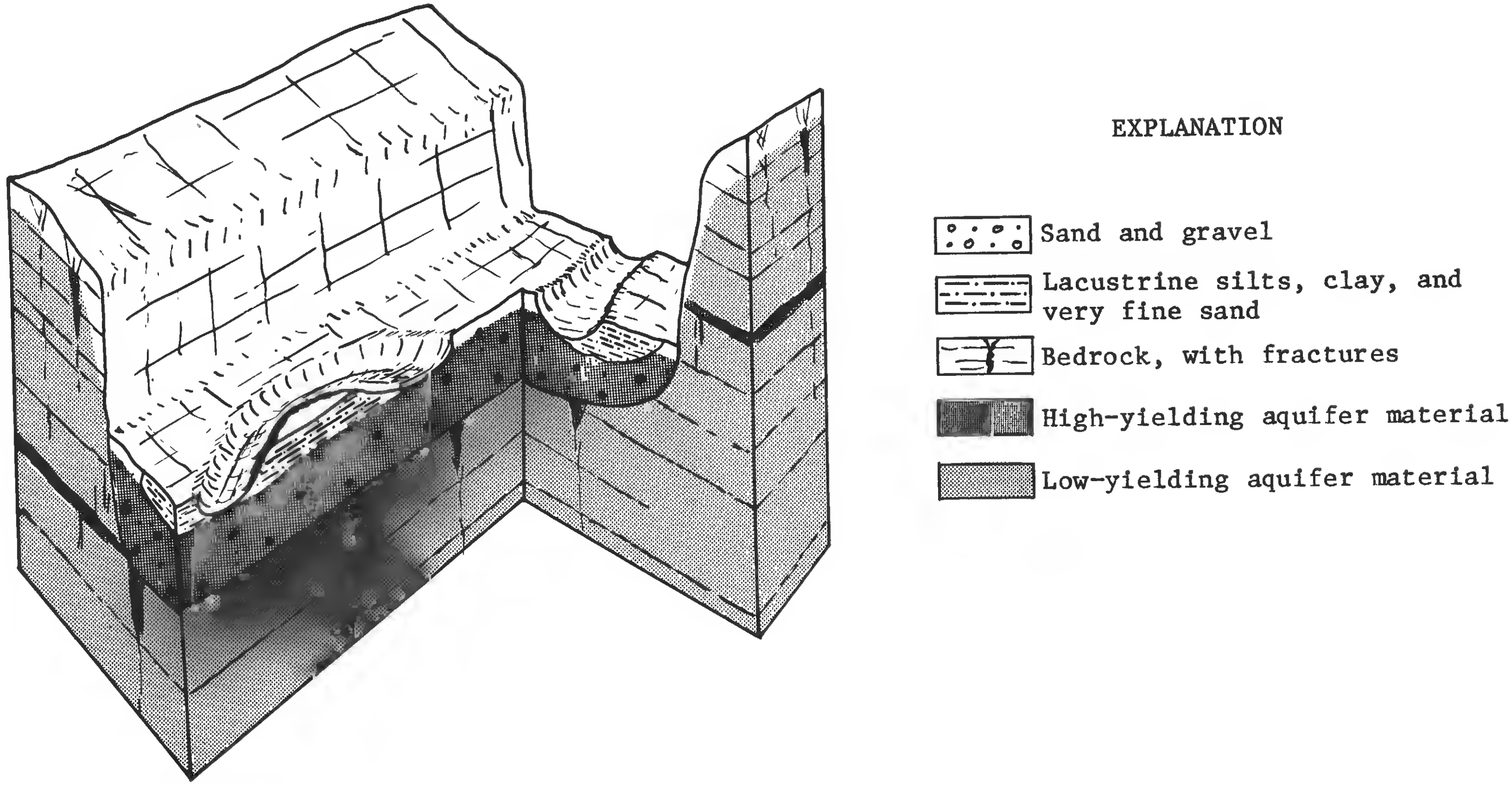


Figure 5B.--Geology and hydrology typical of valleys where streams have been relocated as a result of glacial activity. These steep-walled gorges cut in bedrock (or locally in till) are occupied by large streams. Valley floors are generally about 1,000 feet wide and underlain by 40 feet or less of coarse-grained stratified drift.

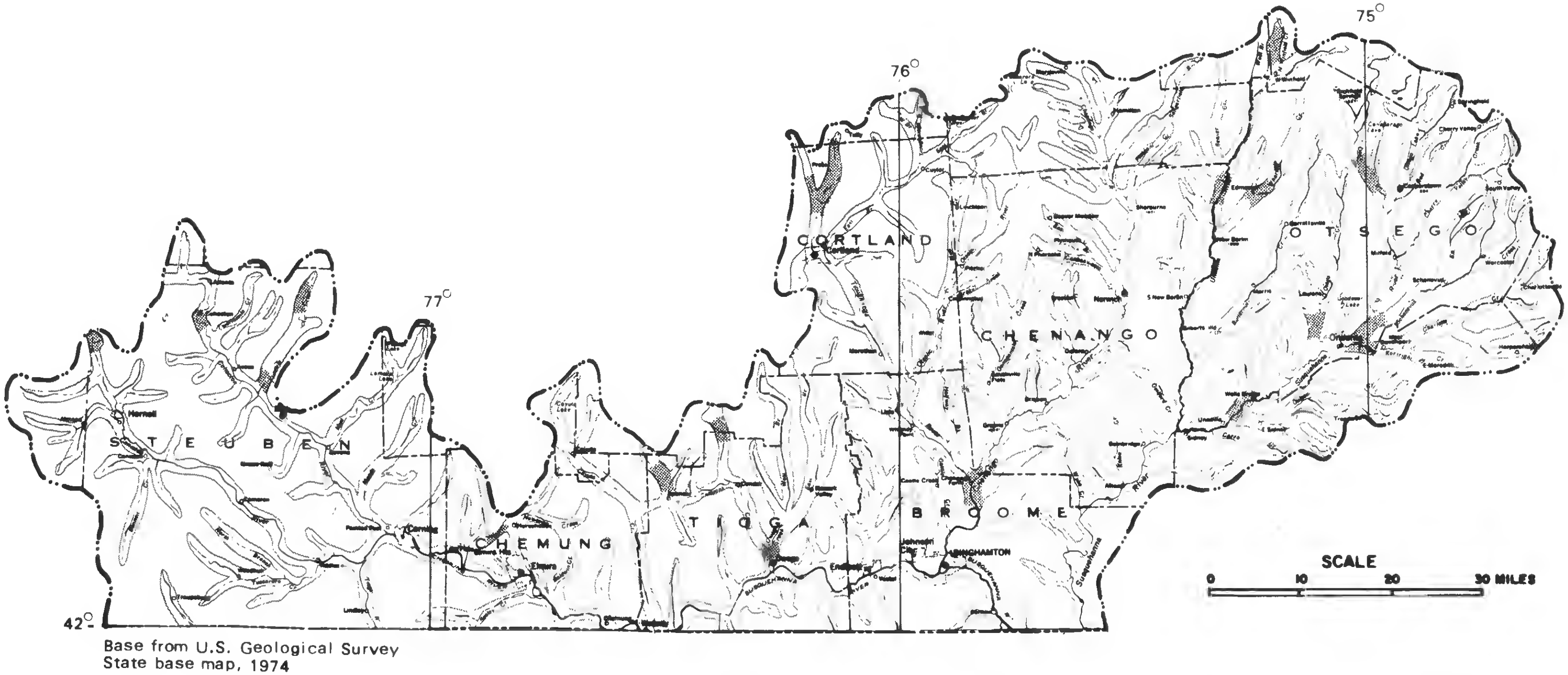


Figure 6A.--Index map showing location of valleys typified in figure 6B.

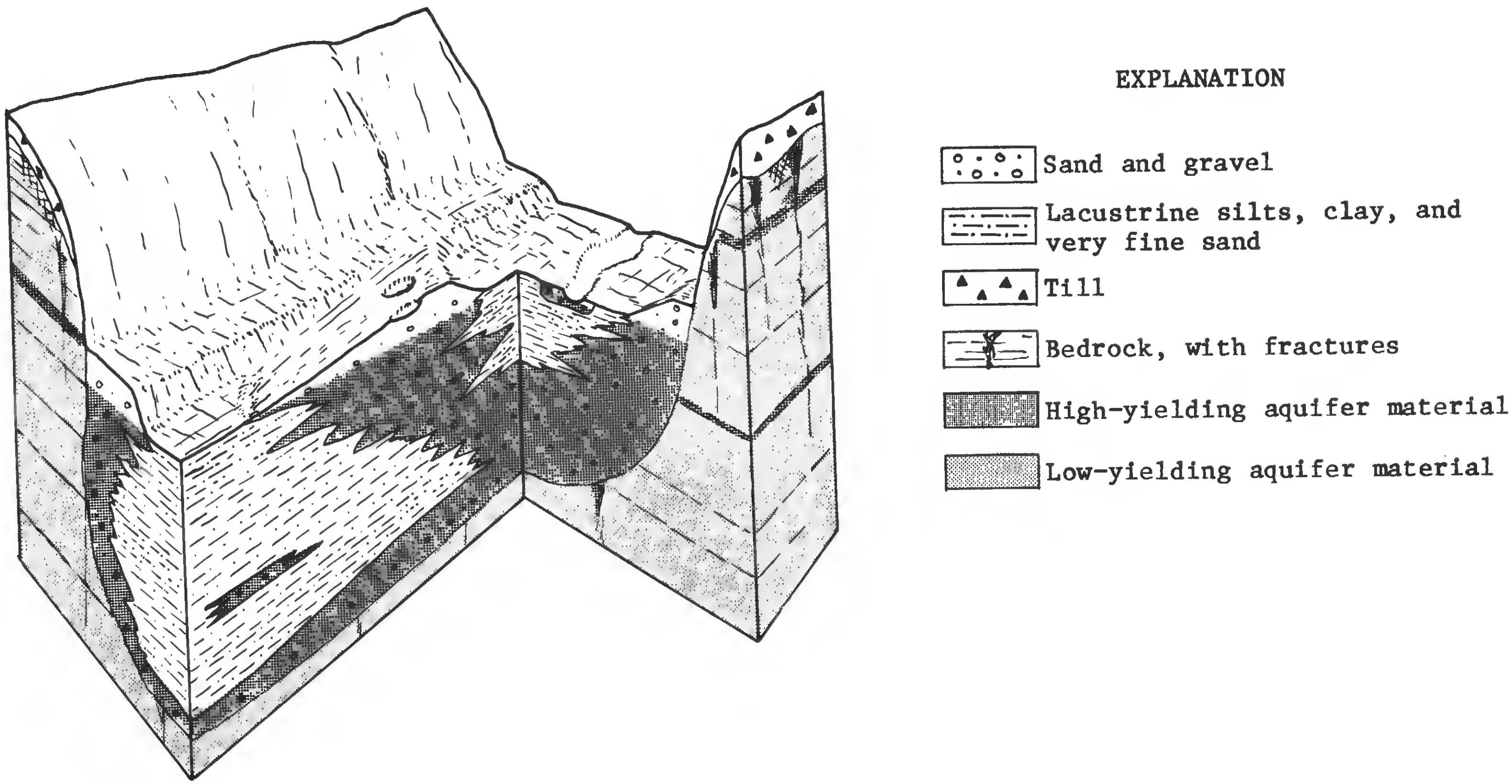


Figure 6B.--*Geology and hydrology typical of valley reaches where an active ice tongue deposited a recessional moraine. These short reaches of broad valleys are choked with stratified drift in the form of high terraces and irregular landforms across the entire valley. Many tens of feet of sand and gravel ranging from silty to clean are inferred to prograde across lake clays in a downstream (southerly) direction and to extend at least a short distance upstream beneath younger lake clays.*

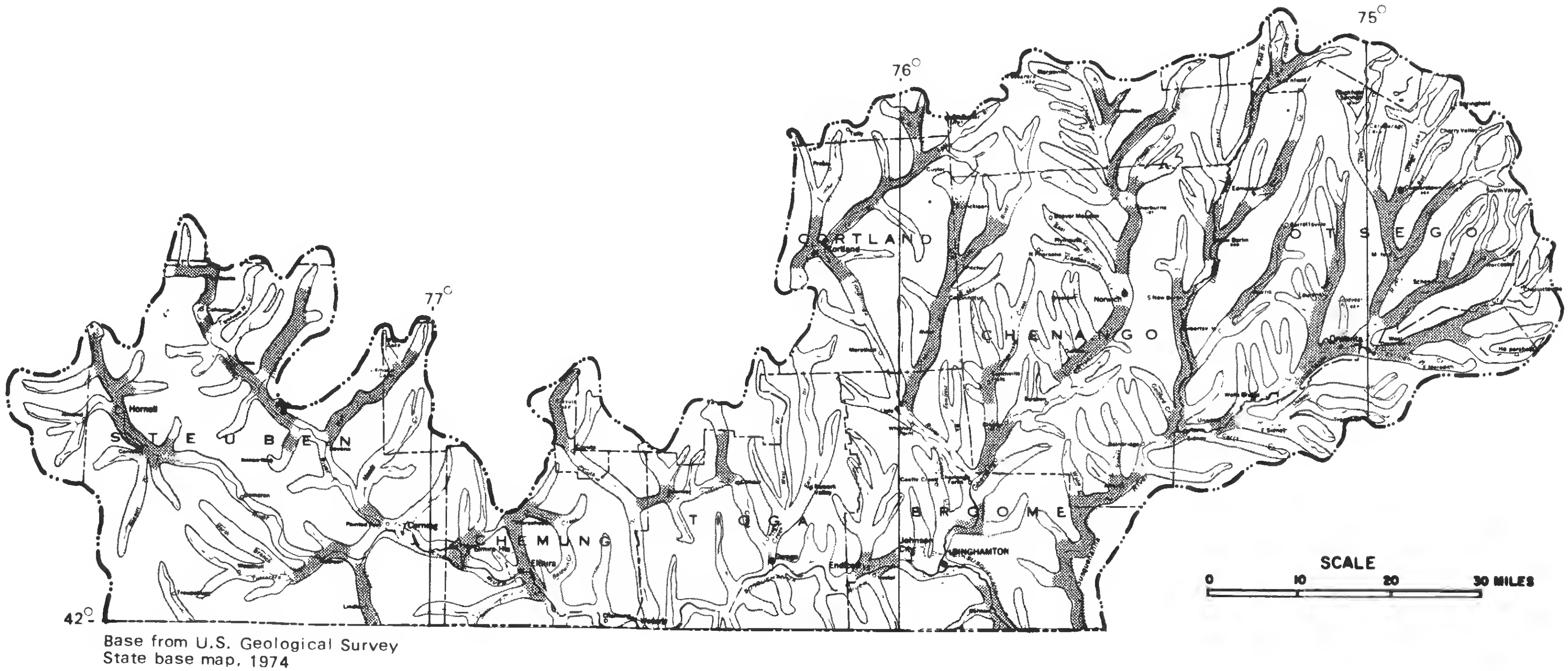


Figure 7A.--Index map showing location of valleys typified in figure 7B.

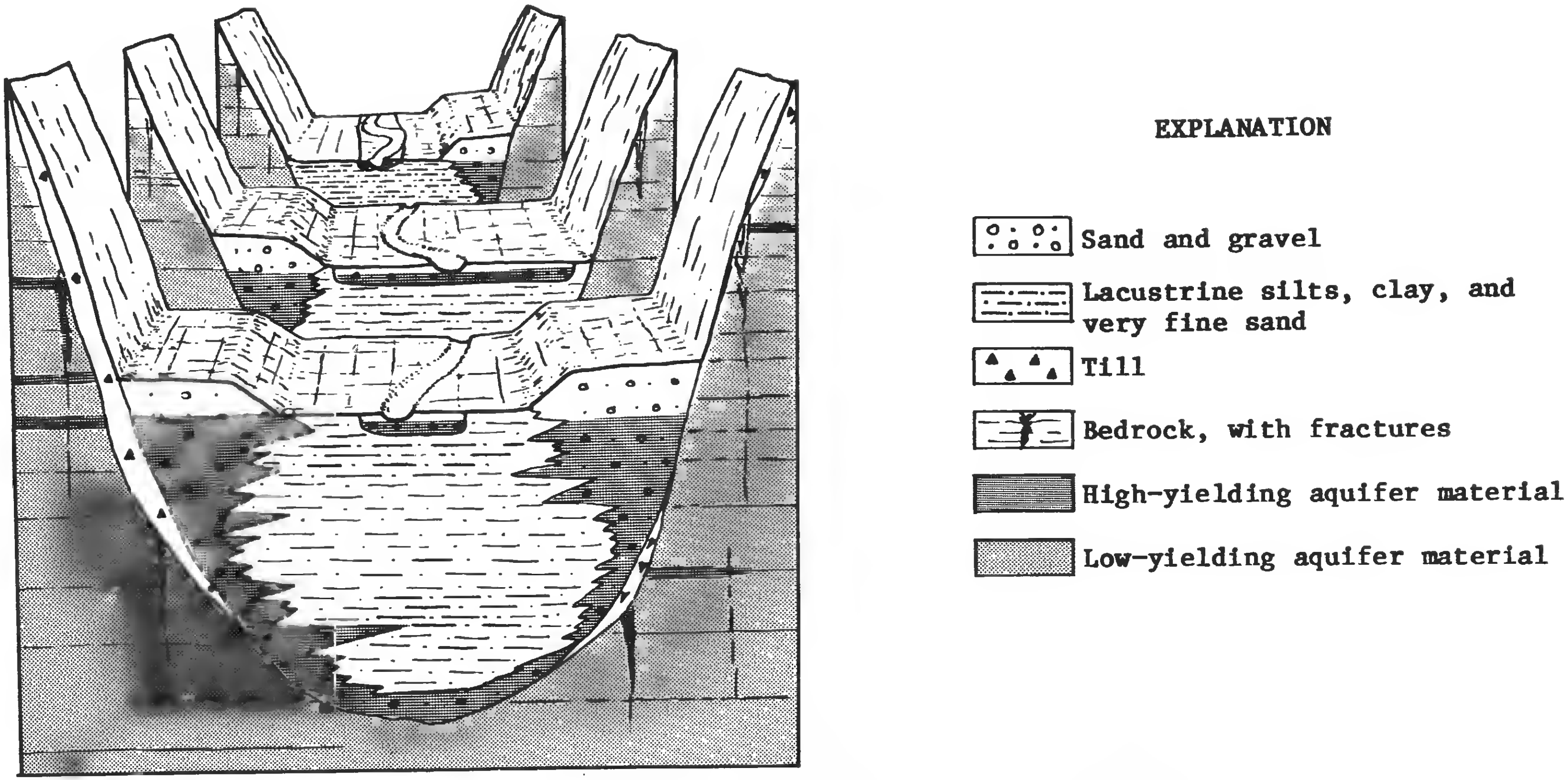
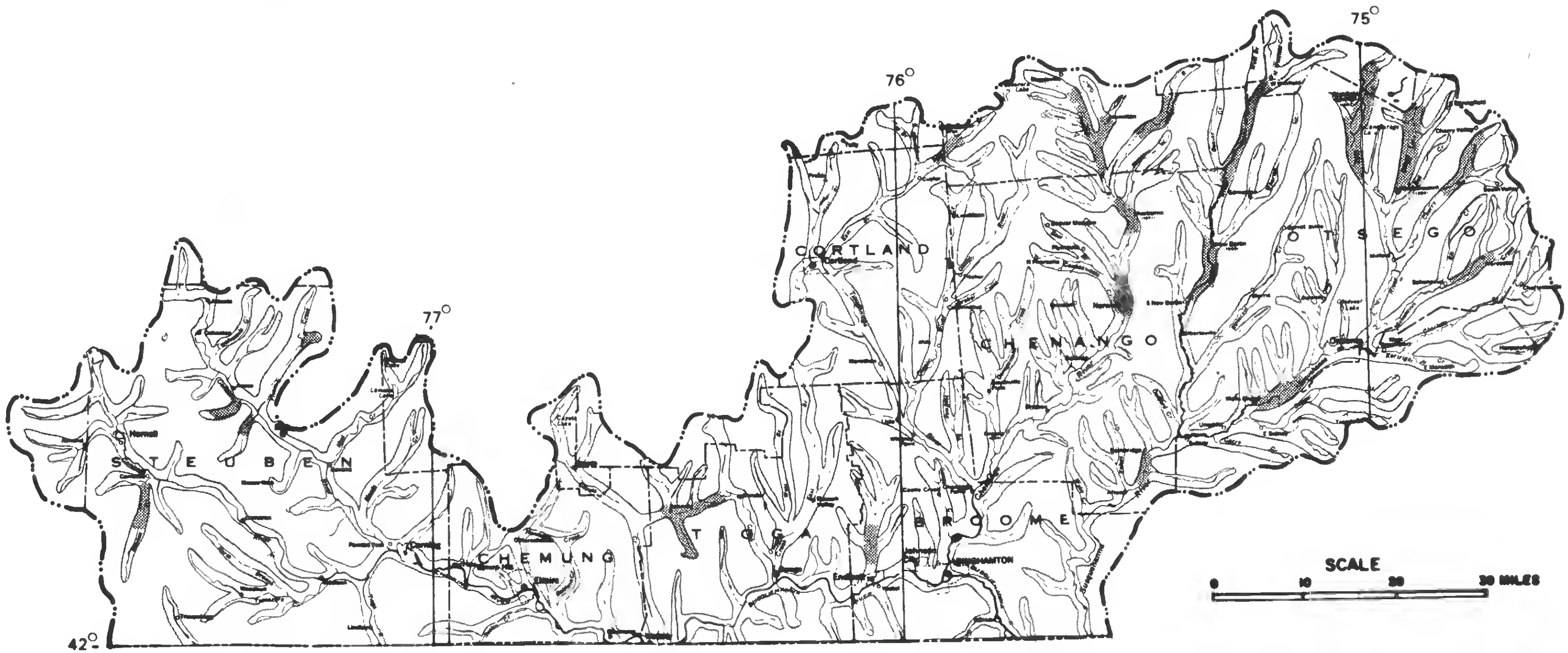


Figure 7B.--Geology and hydrology typical of valley reaches filled during slow retreat of the terminus of an active tongue of ice. The higher terraces that border these broad valleys are underlain chiefly by sand and gravel; beneath the flood plain is a thin layer of alluvial sand and gravel over thick, fine-grained lacustrine sediments. Depth to bedrock is commonly a few hundred feet.



Base from U.S. Geological Survey
State base map, 1974

Figure 8A.--Index map showing location of valleys typified in figure 8B.

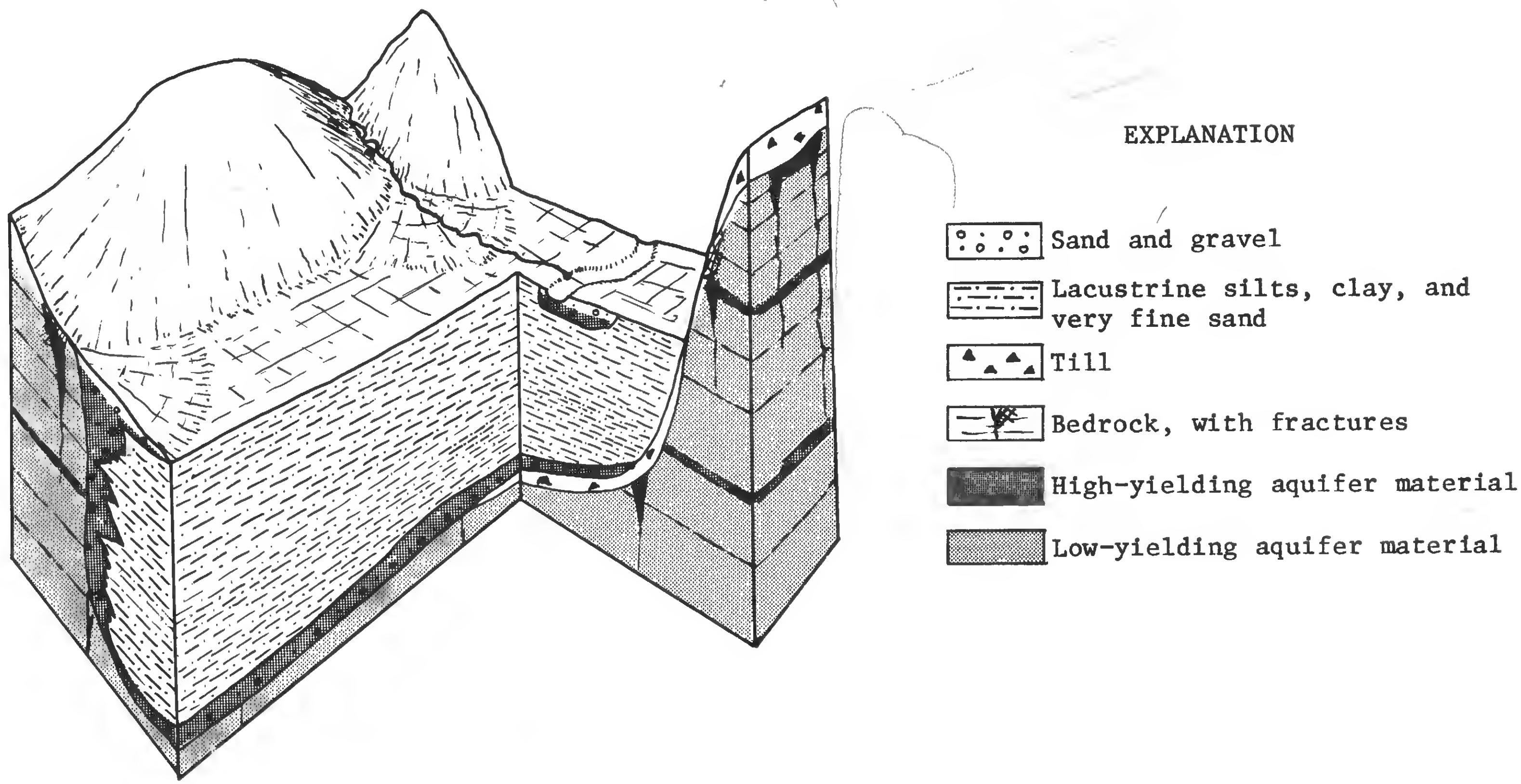


Figure 8B.--*Geology and hydrology typical of valley reaches where an active ice tongue retreated rapidly. These broad valleys have relatively flat floors that are close to stream grade and lack the bordering terraces of figure 7B; valley fill is chiefly fine-grained sediment except close to the mouth of tributary valleys draining areas of 15 square miles or more. Depth to bedrock is commonly several hundred feet.*

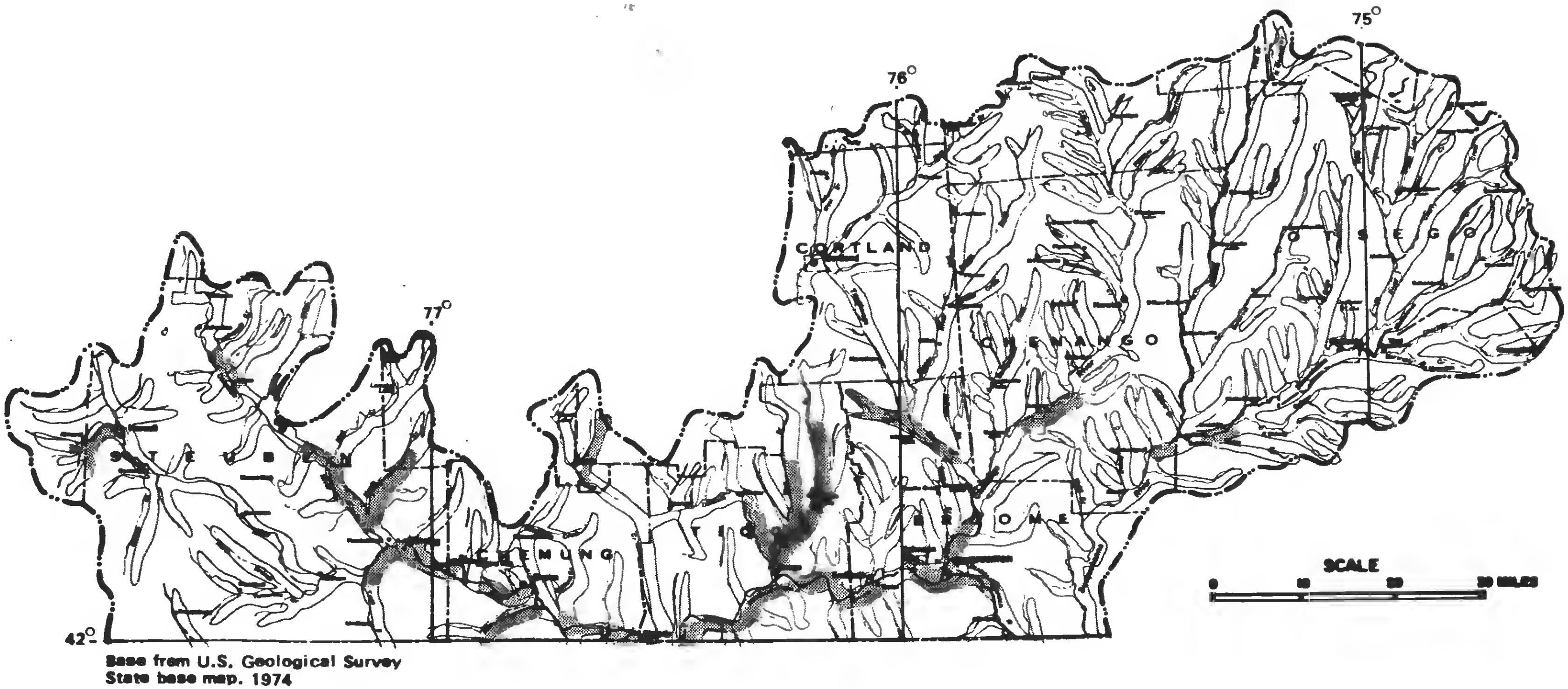


Figure 9A.--Index map showing location of valleys typified in figure 9B.

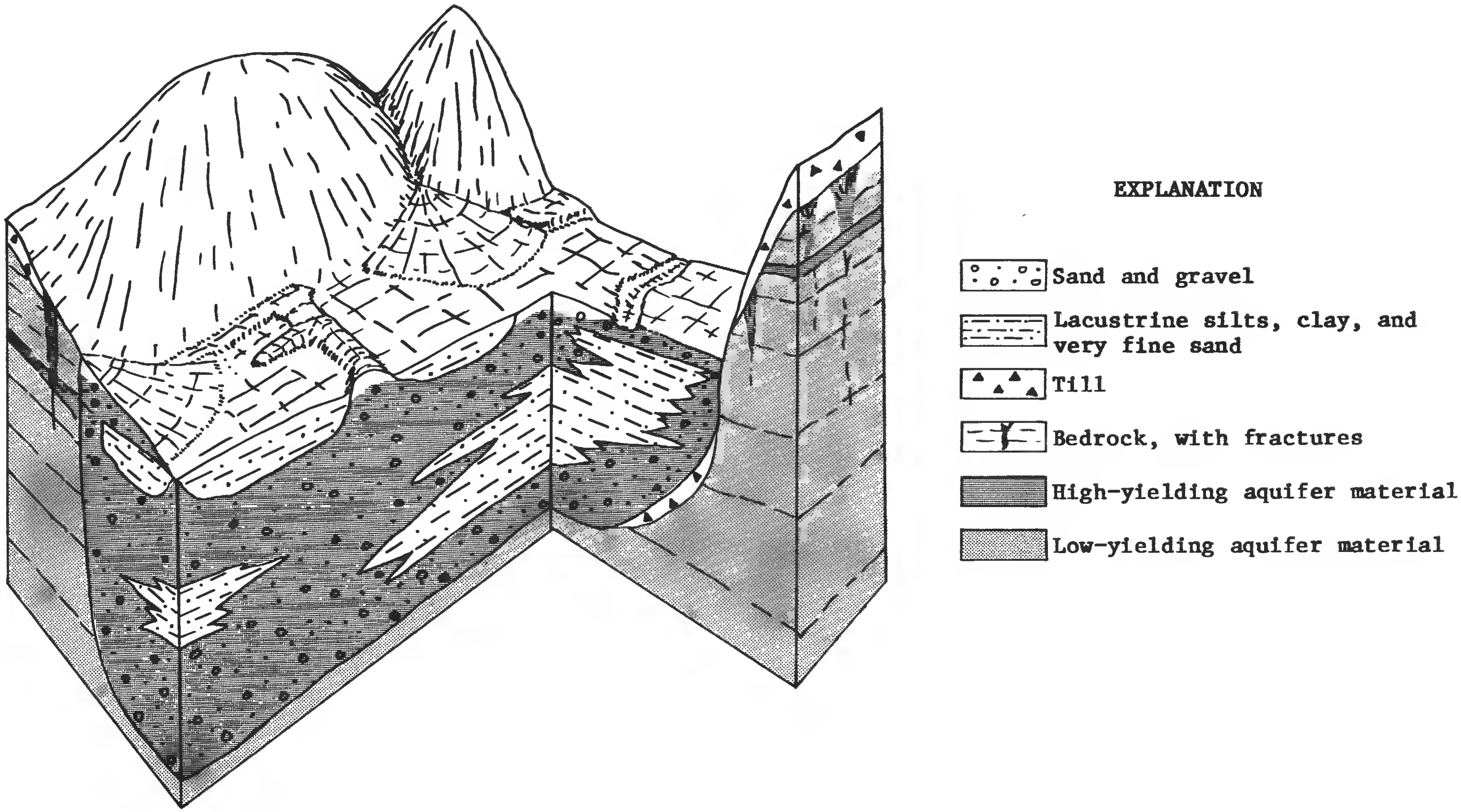


Figure 9B.--Geology and hydrology typical of valleys where ice stagnated and wasted. These are broad valleys, commonly oriented east-west; bedrock is typically less than 100 feet below stream grade. The stratified drift is chiefly silty to clean sand and gravel but contains numerous lenses of fine-grained lacustrine sediments. Knolls and dimpled terraces are common.

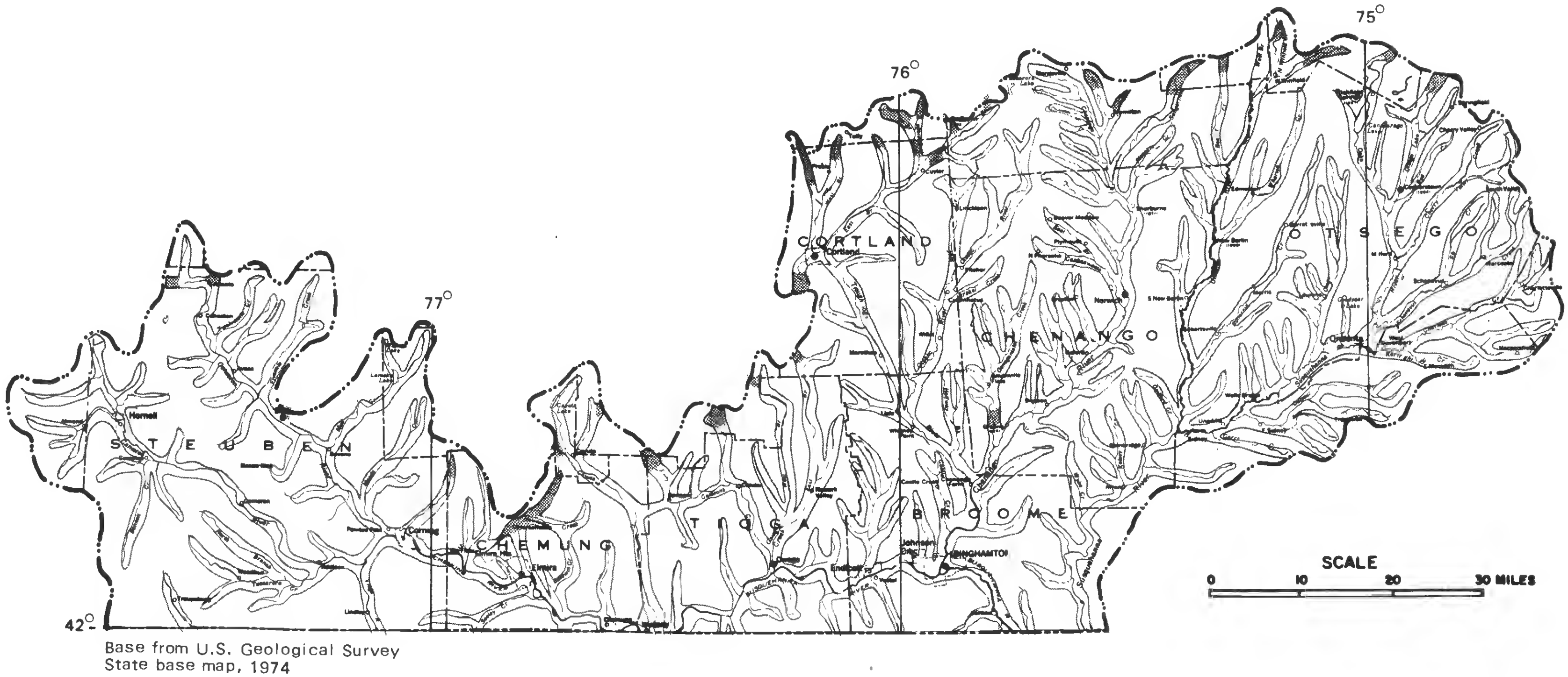


Figure 10A.--Index map showing location of valleys typified in figure 10B.

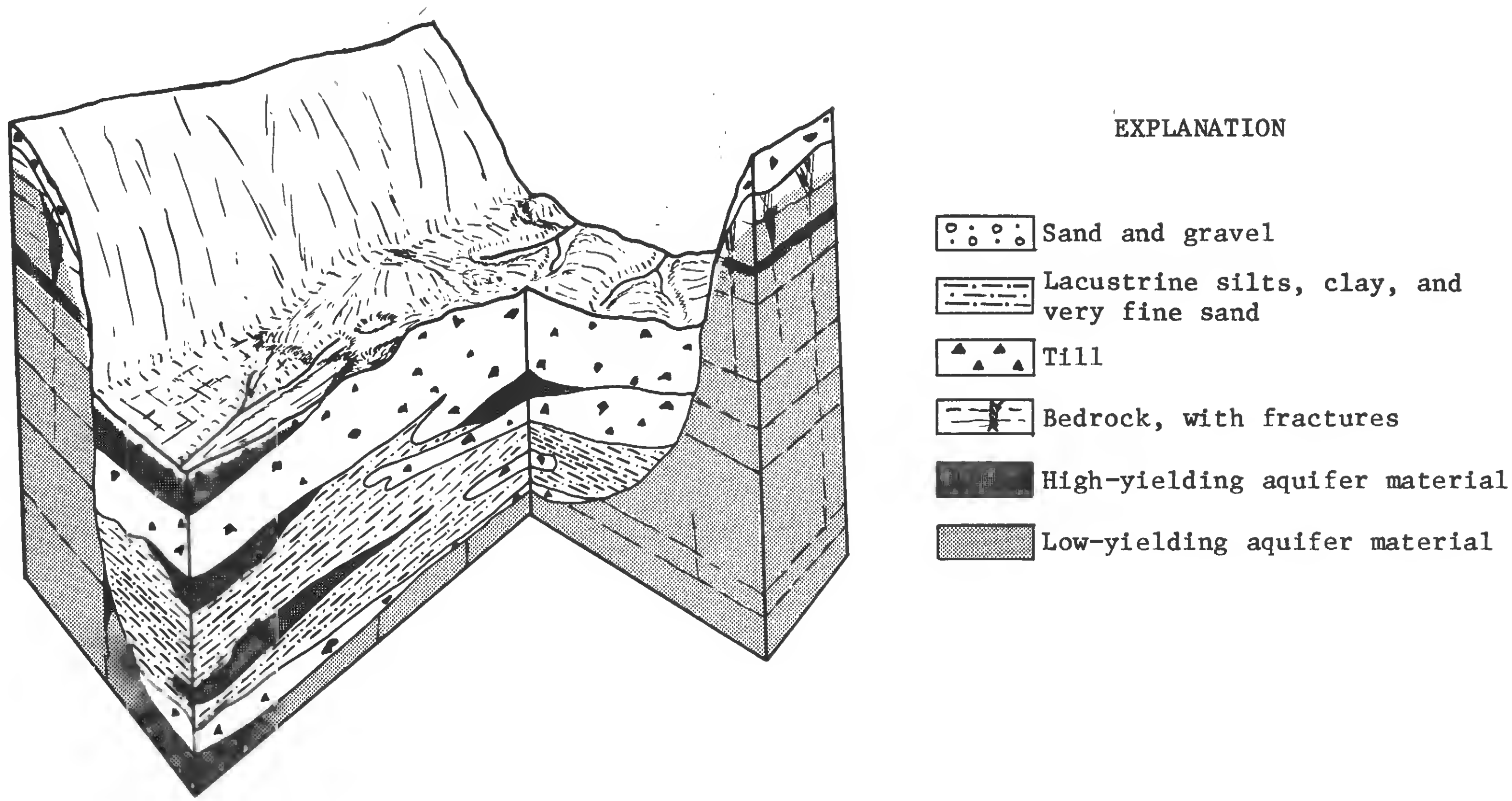


Figure 10B.--Geology and hydrology typical of Valley Heads moraine. The northern divide of the Susquehanna River basin intersects several broad valleys, carved by repeated flows of meltwater and of ice (Coates, 1966). Near the divide, valley topography is typically irregular or hummocky, and the underlying bedrock surface declines steeply to the north (Kirkland, 1970). The thick valley fill typically consists of silt, clay, and glacial till with incidental thin lenses of sand and gravel.

Quantitative Evaluation of Stratified-Drift Aquifers

Planners, consultants, and water managers need not only an understanding of aquifer distribution (such as provided by figs. 4-10) but also a means of predicting how much water could be withdrawn from aquifers and what effect withdrawals would have on streamflow and water quality. Hollyday (1969) analyzed yields and costs of individual wells in the Susquehanna River basin in terms of aquifer thickness and position but did not evaluate aquifer yield. Randall (1977) estimated yields obtainable from a stratified-drift aquifer in Binghamton and Johnson City under several water-management schemes but did not extend the estimates to other aquifers. The following sections of this report include (1) a quantitative reinterpretation of aquifer thickness and position (pl. 1) based in part on new data; (2) a compilation of aquifer dimensions and properties useful in estimating yield, including water-storage capacity, area of streambeds crossing each aquifer, and materials inferred to border each aquifer (table 4, at end of report); and (3) a method of estimating aquifer yield that takes into account not only the aquifer dimensions and properties compiled but also regional average rates of recharge from several categories of precipitation and streambed infiltration.

Aquifer Properties

As a first step toward evaluating yield of stratified-drift aquifers in the Susquehanna basin, a computer program named AQUILIST was devised to tabulate dimensions and other properties of those aquifers and to calculate several derived properties, including storage. The dimensions tabulated in AQUILIST describe only simple rectilinear shapes--tabular or wedge-shaped aquifer sections. Therefore, aquifers thought to have more complex shapes were divided into several rectilinear parts, with each part treated as a separate aquifer. This approach facilitates analysis even though it causes some inconsistency between the idealized aquifer distribution shown in figures 4-10 and the aquifer map (pl. 1) on which the position of each aquifer identified for AQUILIST is shown. Six computer cards were used to compile data for each aquifer, and on each card the data were entered in seven fields of 10 spaces each. The last 10 spaces (71-80) on each card were used to identify the aquifer as follows:

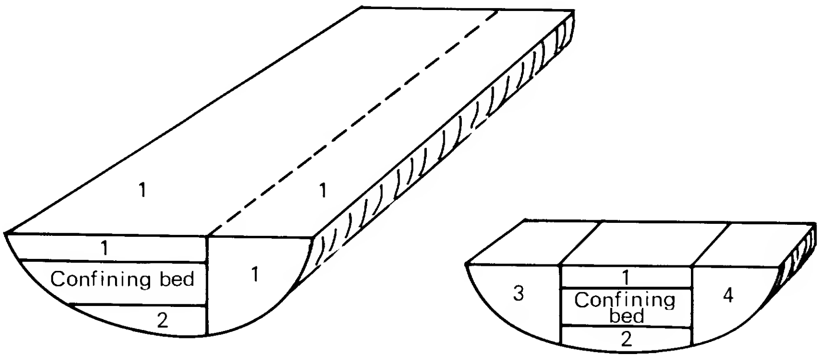
Spaces 71-74 contain the abbreviated name of the valley in which the aquifer is found. (Valley names and abbreviations are listed in table 2, p. 30.)

Spaces 75-77 indicate the number of valley miles between aquifer and valley mouth. The mouths of the Susquehanna and Chemung valleys were arbitrarily set at the State line at Waverly; all other valley mouths were set where the valley walls join those of a larger valley. Valley miles used here should not be confused with river miles as measured by the U.S. Army Corps of Engineers; valley miles were used because they are more easily measured off than river miles and because evolution of a river system causes the location of river-mile points to vary with time.

Space 78 indicates aquifer position within the valley, as illustrated in figure 11.

Space 80 contains a number from 1 to 6 to order the six cards required for each aquifer.

For example, one aquifer is identified as COHC 181. COHC refers to the Cohocton River valley (table 2); the first two digits of 181 indicate that the center of the aquifer is approximately 18 valley miles upstream from the mouth of the valley at Painted Post, and the third digit is the code for a surficial aquifer along the center or side of the valley with its long dimension parallel to the valley and the side with lowest average water level downvalley (fig. 11). The six cards required to describe this aquifer are thus labeled COHC 181 1, COHC 181 2, COHC 181 3, etc.



CODE	DEFINITION	
1	Surficial (water-table) aquifer; lowest water level is on downvalley side	
2	Buried (artesian) aquifer	
3	Right side of valley (facing downstream)	Surficial aquifers; lowest water level is on side near center of valley.
4	Left side of valley (facing downstream)	

Figure 11.--Aquifer positions treated by AQUILIST and computer code for each.

Measurements (where available) or estimates of 39 aquifer properties were supplied for each of the 550 aquifers identified on plate 1. The dimensions and properties used to describe each aquifer are illustrated and identified by code names in figure 12. As more data become available, aquifer descriptions can be revised or new aquifers added with the aid of definitions given in the following list. A set of data provided as input to AQUILIST for aquifer COHC 181 is shown in figure 13. Complete output from AQUILIST includes all 39 properties described in figure 12 and in the following list, plus several derived properties calculated by the computer. Selected output properties for each aquifer are tabulated in table 4 (at end of report); a complete listing of all output and a description of the program may be obtained from the U.S. Geological Survey office in Albany, N.Y.

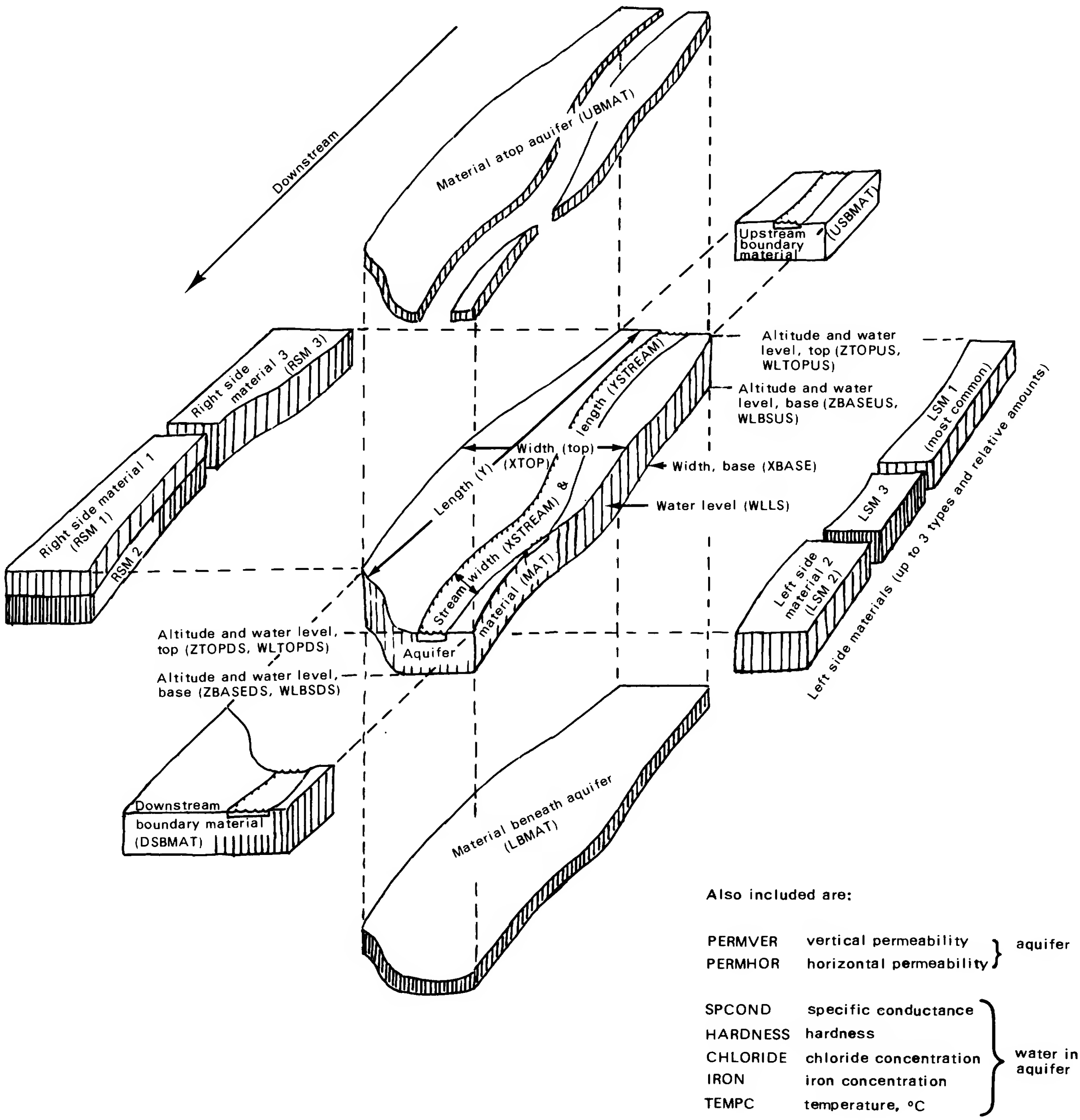


Figure 12.--Aquifer properties tabulated by AQUILIST.

List of Aquifer Properties Compiled for AQUILIST

[Within each group of properties, code names and definitions are listed in order of appearance on computer cards]

<u>Aquifer dimensions</u>

Y = horizontal dimension of aquifer between ZTOPUS and ZTOPDS (described below), approximately parallel to water table or potentiometric gradient

XTOP = average horizontal dimension perpendicular to Y, at upper surface of aquifer

XBASE = average horizontal dimension perpendicular to Y, at lower surface of aquifer

ZTOPUS = elevation of top of aquifer at that border having highest water level

ZBASEUS = elevation of base of aquifer at same horizontal location as ZTOPUS

ZTOPDS = elevation of top of aquifer at that border having lowest water level, opposite ZTOPUS

ZBASEDS = elevation of base of aquifer at same horizontal location as ZTOPDS

Note that ZTOPUS and ZTOPDS are on opposite ends of the aquifer. The aquifers are divided in such a way that this relationship is always true. If the shape of a single aquifer were such that this relationship were not true, the aquifer would be split into smaller units until this relationship could be obtained for each segment.

<u>Materials in or bordering aquifer</u>

MAT = material of which aquifer is composed. A symbol representing aquifer material is placed in the last column of the 10-column field allotted to this aquifer property on the computer cards. Constraints imposed by computer programs available when AQUILIST was designed limited the number of symbols to six. The symbols are as follows:

G = well-sorted gravel, usually fine gravel and coarse sand

H = well-sorted, clean sand

N = sand and gravel, with some silt and clay

L = fine sands, silts, and clay

B = bedrock (shale and siltstone in Susquehanna River basin)

T = till: unsorted boulders, gravel, sand, silt, and clay

If a numeric value for hydraulic conductivity is present in the PERMHOR field (described below), AQUILIST substitutes that value for the material symbol. Otherwise, AQUILIST replaces the material symbol by an assigned hydraulic conductivity value represented as follows; in gallons per day per square foot.

G = 10,000	L = 1
H = 1,000	B = 0.1
N = 100	T = 0.01

These values were obtained from Todd (1959, p. 53) as being approximate values expected in the materials that the material symbols represent.

The following material fields may be coded with the same symbols, the hydraulic conductivity of the unit described, or both.

UBMAT = material immediately overlying aquifer; for a water-table aquifer, symbol for UBMAT is same as for MAT.

LBMAT = lower boundary; material overlain by aquifer. Where a single aquifer overlies or underlies more than one type of earth material, the original aquifer may be divided into as many aquifers as necessary to obtain a single overlying and underlying material.

USBMAT = upstream boundary material; that material adjacent to aquifer side furthest upstream with respect to the main valley.

DSBMAT = downstream boundary material; that material adjacent to aquifer side furthest downstream with respect to the main valley.

RSM1 = material forming greatest part of right-side boundary of aquifer, looking down the main valley.

PCRSM1 = percentage of total right-side boundary adjacent to RSM1.

RSM2 = second most abundant material adjacent to right side of aquifer.

PCRSM2 = percentage of the total right-side boundary adjacent to RSM2.

RSM3 = third most abundant (least abundant) material adjacent to right side of aquifer.

PCRSM3 = percentage of the total right-side boundary adjacent to RSM3.

LSM1 = material forming greatest part of left-side boundary of the aquifer, looking down main valley.

PCLSM1 = percentage of total left-side boundary adjacent to LSM1.

LSM2 = second most abundant material adjacent to left side of aquifer.

PCLSM2 = percentage of total left-side boundary adjacent to LSM2.

LSM3 = third most abundant (least abundant) material adjacent to left side of aquifer.

PCLSM3 = percentage of total left-side boundary adjacent to LSM3.

Stream dimensions

YSTREAM = total length of any streams in contact with aquifer, measured along center of channel. Small streams are ignored if a large stream is present.

XSTREAM = average width of streams whose length is included in YSTREAM.

Aquifer and ground-water properties

PERMHOR = horizontal hydraulic conductivity of aquifer, in gallons per day per square foot.

PERMVER = vertical hydraulic conductivity of aquifer.

SPCOND = average specific conductance of water in aquifer, in micromhos per square centimeter at 25 degrees Celsius.

HARDNESS = average hardness of water in aquifer, in milligrams per liter as $CaCO_3$.

CHLORIDE = average chloride concentration of water in aquifer, in milligrams per liter.

IRON = average iron concentration of water in aquifer, in milligrams per liter.

TEMPC = temperature of water in aquifer, in degrees Celsius.

Water levels in aquifer

WLTOPUS = static water-level altitude in aquifer at point where ZTOPUS is measured.

WLBSUS = static water-level altitude in aquifer at point where ZBASEUS is measured.

WLTOPDS = static water-level altitude in aquifer at point where ZTOPDS is measured.

WLBSDS = static water-level altitude in aquifer at point where ZBASEDS is measured.

WLRS = static water-level altitude at center of right side of aquifer, looking down water-table gradient from WLTOPUS to WLTOPDS.

WLLS = static water-level altitude at center of left side of aquifer, looking down water-table gradient from WLTOPUS to WLTOPDS.

Table 2.--Abbreviations of stream and valley names in AQUILIST

[Locations are shown on plate 1]

Abbreviation	Name of stream or valley	Tributary to
BENT	Bennett Creek	Canisteo River
BIGF	Big Flats valley	Chemung River
BUTR	Butternut Creek	Unadilla River
CACA	Canacadea Creek	Canisteo River
CATA	Catatonk Creek	Owego Creek
CANI	Canisteo River	Tioga River
CAYU	Cayuta Creek	Susquehanna River
CHAR	Charlotte Creek	Do.
CHEM	Chemung River	Do.
CHEN	Chenango River	Do.
CHER	Cherry Valley Creek	Do.
CHIN	Cheningo Creek	East Branch Tioughnioga River
COHC	Cohocton River	Chemung River
CORN	Cornell Creek	Susquehanna River
DUDL	Dudley Creek	Tioughnioga River
ELK	Elk Creek	Schenevus Creek
ELMB	Elmbois valley	Fivemile Creek
ETIO	East Branch Tioughnioga River	Tioughnioga River
FIVE	Fivemile Creek	Cohocton River
FLY	Fly Creek	Oaks Creek
GENE	Genegantslet Creek	Chenango River
KATT	Kattellville valley	Do.
LABR	Labrador Creek	East Branch Tioughnioga River
MEAD	Meads Creek	Cohocton River
MUD	Mud Creek	Do.
MUDC	Mud Creek	Otselic River
NANT	Nanticoke Creek	Susquehanna River
NEIL	Neil Creek	Cohocton River
NEWT	Newtown Creek	Chemung River
OAKS	Oaks Creek	Susquehanna River
OTEG	Otego Creek	Do.
OTSC	Otselic River	Tioughnioga River
OTTR	Otter Creek	Do.
OWGO	Owego Creek	Susquehanna River
OWEB	East Branch Owego Creek	Owego Creek
OWWB	West Branch Owego Creek	Do.
PAGE	Page Brook	Chenango River
PAYN	Payne Brook	Do.
PONY	Pony Hollow	Cayuta Creek
POST	Post Creek	Chemung River
SANG	Sangerfield River	Chenango River
SCHE	Schenevus Creek	Susquehanna River
SEEL	Seeley Creek	Chemung River
SOBR	South Branch	Catatonk Creek
SUSQ	Susquehanna River	--
TIOG	Tioga River	Chemung River
TIOU	Tioughnioga River	Chenango River
TROU	Trout Brook	Tioughnioga River
TWEL	Twelvemile Creek	Cohocton River
UNAD	Unadilla River	Susquehanna River
UNWB	West Branch Unadilla River	Unadilla River
VNET	Van Etten valley	Cayuta Creek
WHAR	Wharton Creek	Unadilla River
WILL	Willseyville Creek	Catatonk Creek
WTIC	West Branch Tioughnioga Creek	East Branch Tioughnioga River
WTIO	West Branch Tioughnioga River	Tioughnioga River

14800.0	3500.0	3500.0	1130.0	1050.0	1100.0	1020.0	COHC 18101
Y	*XTOP*	*XBASE*	*ZTOPUS*	*ZBASEUS*	*ZTOPDS*	*ZBASEDS*	*SEQ NO*
N	N	T	N	N	15300.0	110.0	COHC 18102
MAT	*UBMAT*	*LBMAT*	*USBMAT*	*DSBMAT*	*YSTREAM*	*XSTREAM*	*SEQ NO*
B	B	357.0	220.0	7.0	0.06		COHC 18103
PERM HOR	*PERM VER*	*SPCOND*	*HARDNESS*	*CHLORIDE*	*IRON*	*TEMPC*	*SEQ NO*
1130.0	1130.0	1100.0	1100.0				COHC 18104
WL TOPUS	*WL BSUS*	*WL TOPDS*	*WL BSDS*	*WL RS*	*WL LS*	*BLANK*	*SEQ NO*
N 20.0		T 50.0		B 30.0			COHC 18105
RSM1	*PC RSM1*	*RSM2*	*PC RSM2*	*RSM3*	*PC RSM3*	*BLANK*	*SEQ NO*
N 40.0		T 40.0		B 20.0			COHC 18106
LSM1	*PC LSM1*	*LSM2*	*PC LSM2*	*LSM3*	*PC LSM3*	*BLANK*	*RIVER VALLEY* *MIDLE NT* *ISEQ NO*

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Figure 13.--AQUILIST data set for a typical aquifer (COHC 181). Abbreviated code name of each variable defined in text and figure 12 is given below value for that variable.

Aquifer yield

General Approach to Estimating Yield

Many recent appraisals of the water resources of large drainage basins in New York and New England have evaluated potential aquifer yield by determining representative regional rates of ground-water recharge and applying those rates to the dimensions of each aquifer or area of stratified glacial drift (Cohen and others, 1968, p. 24-46; Crain, 1974, p. 45, pl. 3; Kantrowitz, 1970, p. 67; LaSala, 1968, p. 54; Randall and others, 1966, p. 66; Randall, 1977; Cervione and others, 1972, p. 46-47). Several components of recharge were considered in these studies and are explained in the following paragraphs.

Precipitation on the aquifer.--Where sand or gravel are present at land surface, nearly all rain and melting snow infiltrates, and about half reaches the water table as recharge and flows slowly to streams or wells. (The rest is returned to the atmosphere by plants or evaporation.) Thus, the annual volume of recharge from precipitation to a surficial aquifer depends principally on the extent of surficial sand and gravel and on the annual precipitation rate. Differences in infiltration capacity of the soil and in method of computation are partly responsible for differences in the average annual recharge rates given in the reports referred to above.

Precipitation on upland hillsides adjacent to the aquifer.--Most stratified-drift aquifers are bordered by till-covered hillsides. Where the till contains a large percentage of silt and clay, as in the Susquehanna River basin, only a small part of the water from heavy rain or snowmelt can infiltrate beyond the top foot or two; the excess moves downslope in rivulets or through shallow openings in the soil. Where upland hillsides slope directly toward a stratified-drift aquifer on the valley floor (rather than toward an upland stream), storm runoff may infiltrate to the water table after it reaches the permeable sand or gravel in the valley. In addition, a small but steady flow of ground water moves through the bedrock from upland areas toward the major valleys and, when it reaches a valley, it seeps into the stratified drift. Recharge from these upland sources was estimated separately in some of the studies previously referred to; in others, it was included with estimates of recharge from precipitation on the aquifer. Annual recharge to a particular aquifer from upland sources depends principally on annual precipitation and on the size of upland areas that slope directly toward that aquifer. In the Susquehanna River basin, area of upland sloping directly toward valley aquifers is nearly constant per unit length of aquifer along the valley.

Infiltration from streams.--Where the water level in a surficial stratified-drift aquifer is lower than the water surface in a stream crossing the aquifer, stream water will infiltrate into the aquifer. This situation is uncommon in the Susquehanna River basin under natural conditions except where small streams enter major valleys (Ku and others, 1975); losses from small streams by natural infiltration in such localities were evaluated by Randall (1978).

Infiltration can be induced from stream reaches that do not lose water naturally if the water levels in surficial aquifers are sufficiently lowered by pumping. The rate of induced infiltration depends on many factors,

including the distribution of wells and pumping rates, the distribution of vertical and horizontal hydraulic conductivity within the aquifer, and changes in stage and water temperature within the stream. However, for most aquifers some arrangement of wells could probably be devised to lower water level below streambed level in the part of the aquifer beneath the stream; if so, the minimum potential infiltration would occur under conditions of low stream stage and may be treated as a function of the hydraulic conductivity of the streambed and nearby parts of the aquifer (which together may be termed "effective streambed permeability") and the area and minimum flow of the stream. Measurements in Wisconsin and Colorado led Moore and Jenkins (1966, p. 696) to suggest 20 gallons per day per square foot as a reasonable estimate of potential infiltration rate for alluvial streams; data from New York are not yet adequate to improve on this generalization. Much larger rates were measured under natural conditions on the alluvial fans of small tributary streams in the Susquehanna River basin; these rates averaged at least 650 gallons per day per lineal foot of channel or at least 50 gallons per day per square foot (Randall, 1978; written commun.). However, infiltration rates of 1 to 2 gallons per day per square foot were reported for two reaches of large streams near Binghamton by Randall (1977, p. 66-67), who thought those rates could be increased but lacked measurements of streamflow losses or substream heads to confirm calculations. Potential streambed infiltration must be at least as large as average recharge to the underlying aquifer from other sources in wet years because, under nonpumping conditions, the water that enters that aquifer from other sources will exit largely by seepage through the streambed.

Need for storage.--Recharge to surficial aquifers from local sources, that is, from precipitation on the aquifer and adjacent hillsides and from small streams that lose water as they cross the aquifer, is by no means constant. The rate falls far below the average annual rate for 4 to 6 months during the growing season in most years, and for even longer periods in drought years (Crain, 1974, p. 40-46; Randall, 1977, p. 28, 56). Where ground-water withdrawals approach the average annual recharge rate from local sources, the temporary seasonal deficiency in local recharge would ordinarily be made up by a temporarily larger rate of induced recharge from streams crossing the aquifer. However, if the master stream crossing the aquifer were very small, or if induced recharge were already occurring at the maximum potential rate, or if the well field could be laid out to minimize loss in flow from the master stream, then ground-water withdrawals during periods of deficient local recharge would be derived largely from water stored in the aquifer.

There would be little reason to speculate about the maximum rate at which water could infiltrate through a streambed if that rate exceeded the rate at which water could be withdrawn by wells. However, analysis of well performance (table 1) indicates that wells of conventional design can generally be expected to yield more than 500 gallons per minute in aquifers 10 to 40 feet thick, and more than 1,500 gallons per minute in thicker aquifers. Simple calculations based on estimated aquifer permeability led MacNish and others (1969) to suggest that such wells could be spaced about 500 feet apart along both sides of a stream without undue interference. Pumpage of this magnitude would generally be sufficient to withdraw all water infiltrating at 20 gallons per day per square foot from streams 150 feet wide crossing aquifers 10 to 40

feet thick, or from streams 450 feet wide crossing thicker aquifers. Most of the aquifers listed in table 4 are within these limits. However, where the largest streams cross aquifers less than 40 feet thick, conventional wells 500 feet apart may not yield enough to induce infiltration at 20 gallons per day per square foot. In such instances, even if infiltration of 20 gallons per day per square foot were possible, it might not be practical because unconventional well arrays of relatively high cost might be required (for example, collector wells, vertical wells of exceptionally efficient design, and(or) numerous closely spaced wells with high pumping lifts and modest individual yields).

During a single growing season, local recharge could be nearly zero for as long as 6 months, so a volume of water equal to half the average annual recharge would have to be available in underground storage to sustain withdrawal at the average annual recharge rate. During the great drought of the 1960's, the cumulative deficiency in runoff in the Susquehanna River basin was equal to about 1.5 years' average runoff (Ku and others, 1975). Recharge to surficial aquifers should have been similarily deficient during that drought. Accordingly, to sustain withdrawals at the average annual recharge rate throughout such a rare drought, the volume of stored water available would have to equal 2 times the average annual recharge (1.5 to meet the long-term deficiency caused by the drought plus 0.5 to meet the normal seasonal deficiency). Recharge from local sources during the dryest year out of 30 years has been estimated to be about 65 percent of average annual recharge (Randall, 1977, p. 16-17); pumpage at an equal rate would still require use of seasonal storage equal to half the annual pumpage but would not require long-term storage.

Given some knowledge of aquifer dimensions and an estimate of what fraction of aquifer volume is drainable pore space (about 20 percent in sand and gravel aquifers), the calculation of how much water is stored in an aquifer is straightforward. However, only a fraction of the stored water can be withdrawn at reasonable cost. Economical withdrawal of large volumes of water requires widely spaced, efficient, large-capacity wells and requires that at least the lower part of the aquifer remain saturated at each well, with greater saturation nearby to provide a water-table gradient toward each well. Trial calculations with mathematical expressions for ground-water flow, and with a digital-computer model of an idealized aquifer, suggest that one-third of the water stored in an aquifer is about the maximum that can be withdrawn without a costly and generally impractical network of small, closely spaced wells.

Buried aquifers.--Where extensive lake beds lie within the stratified drift, any sands or gravels buried beneath the lake beds cannot receive direct recharge from precipitation, storm runoff, or streambed infiltration but must be recharged by ground water from adjacent earth materials. If buried aquifers are in contact with only lake beds, till, and bedrock, recharge will be limited by the low hydraulic conductivity of these materials. However, as suggested by figures 4-10, most buried aquifers are in partial contact with surficial aquifers, chiefly along the sides of the valley and near tributary streams, and thus receive recharge through the surficial aquifers. In such situations, as pointed out by Kantrowitz (1970, p. 68), the yield of both surficial and buried aquifers must be considered as a single unit; withdrawal of water from one will reduce the yield available from the other.

During periods of deficient recharge, the added drain on a surficial aquifer caused by pumping an adjacent buried aquifer may result in withdrawal of more than one-third the storage in the surficial aquifer. However, many buried aquifers are thin and hence not efficiently dewatered by pumping. Therefore, as suggested by digital-computer simulation of an idealized surficial and adjacent buried aquifer thought to be typical of the Susquehanna River basin, one-third of the total storage in the combined system may be treated as an estimate of usable storage. This estimate will generally be conservative because in reality some water would drain into a heavily pumped buried aquifer from adjacent fine-grained sediment; such inflow was not considered in the estimate.

Method of Computation

Potential withdrawal from any of the aquifers identified on plate 1 may be estimated from information presented in this and other reports based on U.S. Geological Survey investigations of water resources in the Susquehanna River basin during the late 1960's. A method for so doing is diagrammed in figure 17 (p. 42-43) and explained in detail below. The next section of this report illustrates application of the method by means of an example.

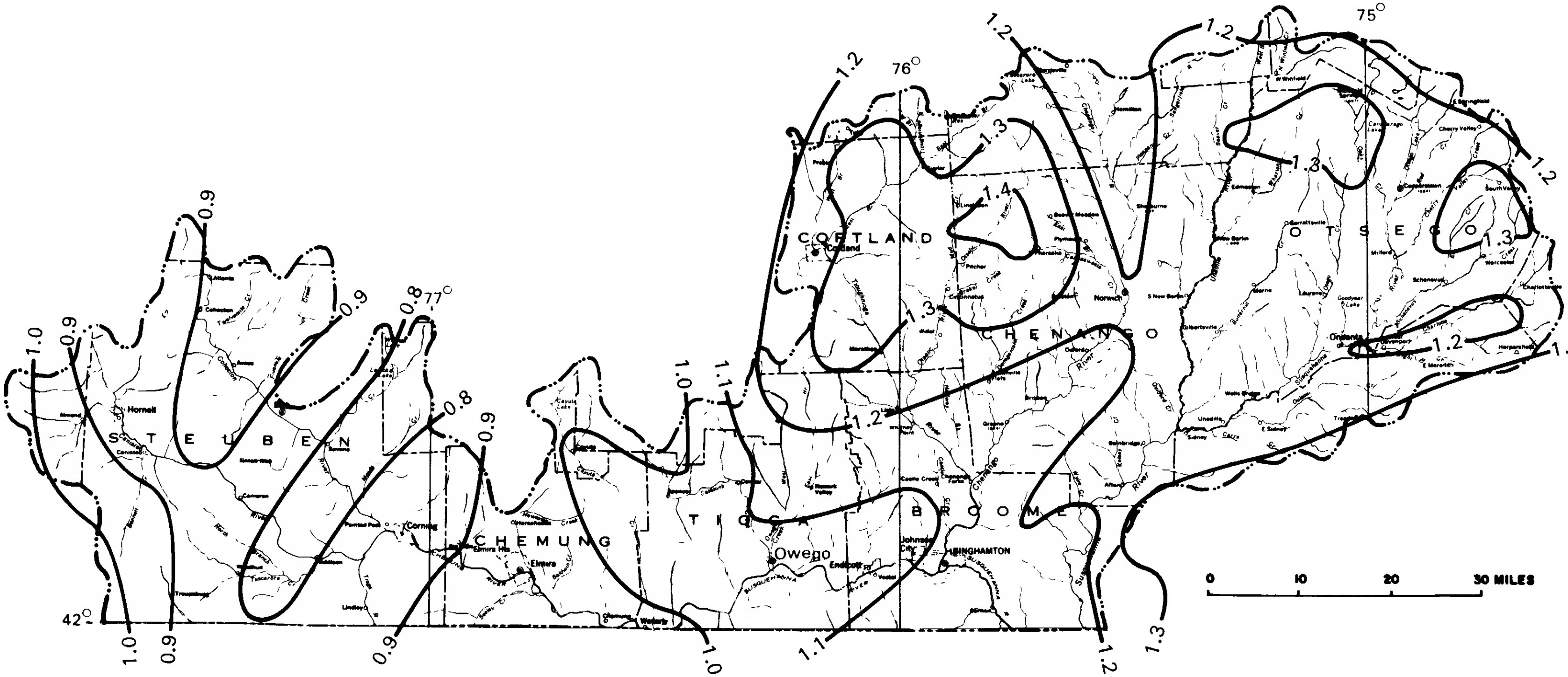
(1) Identify aquifer types and thicknesses in area of interest, as shown on plate 1. Surficial aquifers less than 10 feet thick are unsuitable for large-scale development and may be ignored; most are not assigned as identification code number on plate 1. If only surficial aquifers are shown, skip step 2 and proceed to step 3.

(2) Consider buried aquifers. All buried aquifers are interpreted as being overlain by lake beds and underlain by till, bedrock, or lake beds; however, some are interpreted as being bordered by sand and gravel along at least part of one or more sides. In most places, the sand and gravel is part of a thick surficial aquifer. An estimate of the percentage of side area bordered by sand and gravel is given in table 4 (at end of report) for each aquifer.

(a) If the percentage of sand and gravel bordering a buried aquifer is zero, recharge occurs only by slow seepage through poorly permeable materials. For an estimate of long-term average withdrawal, multiply aquifer area, in square miles (table 4), by 6×10^4 gallons per day per square mile, which provides an estimate of potential leakage through clayey silt under a steep hydraulic gradient.

(b) If the percentage of sand and gravel bordering the sides of the aquifer is appreciably greater than zero, recharge to an adjacent surficial aquifer(s) would probably be available also to the buried aquifer. Estimate withdrawal for the surficial and buried aquifers combined by the same procedure as for a surficial aquifer alone (steps 3-10), but include recharge to the buried aquifer (from step 2a) and include water stored in both buried and surficial aquifers in computing withdrawal from storage (step 7).

(3) Estimate recharge from precipitation directly on surficial aquifers. Multiply aquifer area (table 4) by the average annual rate of recharge from precipitation (fig. 14).



Base from U.S. Geological Survey
State base map, 1974

Figure 14.--Average annual rate of recharge from precipitation to surficial stratified-drift aquifers in the Susquehanna River basin, in million gallons per day per square mile.

(4) Estimate recharge from adjacent hillsides to surficial aquifers. First, multiply aquifer length (table 4) by 0.13 million gallons per day per mile (if west of Owego) or 0.16 million gallons per day per mile (if east of Owego). The location of Owego is shown in figure 14. Then, if the aquifer covers the entire valley width and thus abuts till-covered hillsides on both sides, multiply the first product by 2. These factors are adapted from recharge rates from this source under natural conditions as estimated by Kantrowitz (1970, p. 57, 67) and Randall (1977, p. 60-61); these factors take into account the average area of hillside bordering each mile of valley aquifer.

(5) Estimate recharge from tributary streams crossing surficial aquifers under natural conditions. Refer to a 7.5-minute topographic map (listed in Randall, 1972, fig. 2) and along each tributary draining more than 0.5 square miles note the point where the stream crosses an imaginary line that connects the walls of the main valley on either side of the stream. Then measure the channel length from that point downstream across the aquifer to where channel gradient decreases to 1 percent. Multiply measured channel length by 650 gallons per day per foot to obtain the potential recharge rate in the presence of adequate streamflow. This procedure is adapted from Randall (1978). (If streamflow measurements can be made within the predicted losing reach, or if the channel can be examined, that information can help in estimating the length of the losing reach and the rate of recharge.) Compare the recharge rate thus calculated with long-term flow duration of the stream, which may be estimated from figure 15 for most upland basins. Ku and others (1975) estimated flow duration for specific sites on some streams and discussed regional low-flow relationships that prove helpful in estimating flow duration for basins with more than 5 percent surficial sand and gravel. If streamflow is estimated to fall below the potential recharge rate at times, reduce the estimate of average recharge to allow for the periods of deficient flow.

(6) Add results of steps 2 through 5; the total represents average recharge from local sources--that is, exclusive of any recharge induced from major streams as a result of ground-water development. If wells were placed more than a few hundred feet from the master stream and pumped at a steady rate equal to or less than the average recharge, the water would have nearly constant temperature and chemical quality, and the average annual flow of the master stream at the downstream end of the aquifer would be at least as large as at the upstream end. Even with careful well placement, however, temporary reduction in streamflow due to induced infiltration would be difficult to avoid during seasons and years of below-average recharge.

(7) Convert the average local recharge rate from step 6 to an annual volume, then multiply by 2 to estimate the volume of water in underground storage that would be needed to sustain withdrawal throughout a major drought similar to that of the 1960's at a rate equal to that calculated in step 6. If the volume needed is less than one-third of the total volume of water stored in the aquifer (table 4), the withdrawal rate from step 6 could probably be sustained from storage during such a drought. If the volume needed is much more than one-third the total storage, it would be

costly and generally impractical to install the many closely spaced wells required to obtain that volume from storage, in which case a smaller annual withdrawal that could be sustained from storage may be selected from the curve in figure 16.

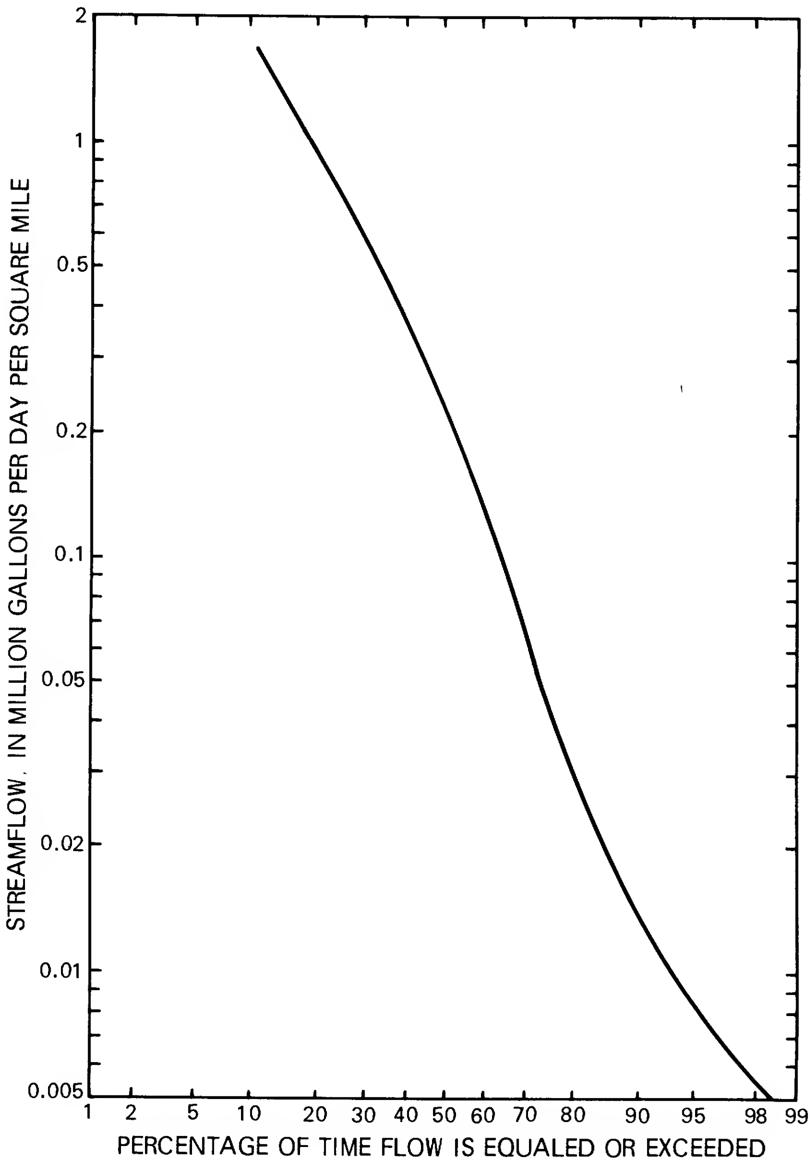


Figure 15.--Average flow duration for streams draining till-covered upland areas (containing less than 5 percent sand and gravel) in the Susquehanna River basin of New York, expressed as a dimensionless ratio to average annual recharge. The curve was developed from data given in Ku and others (1975). To estimate actual flow duration in million gallons per day at any point along a stream draining an upland basin, multiply by drainage area and by average annual recharge as interpolated from figure 14 according to basin location. NOTE: The ordinate scale of figure 15 (above) should be labeled "DIMENSIONLESS STREAMFLOW."

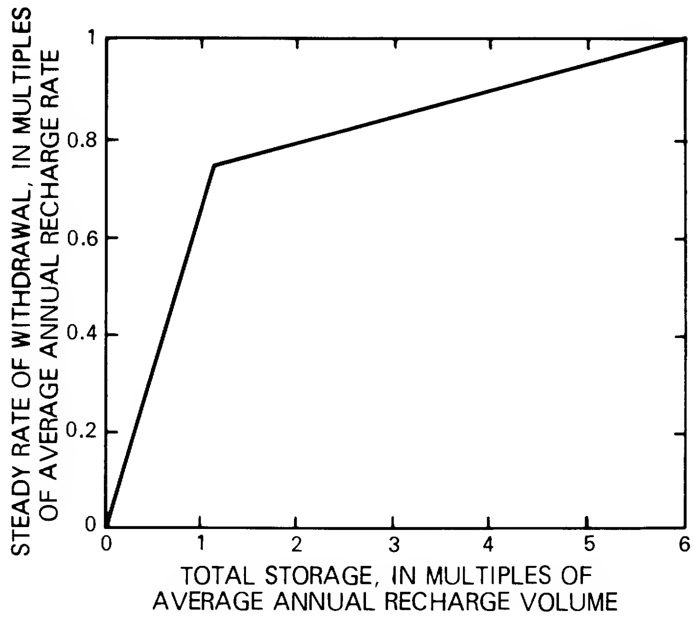


Figure 16.--Estimated maximum rate of withdrawal from storage that could be sustained over a 6-year drought such as that of the 1960's, as a function of storage volume and average recharge. The break in slope of the curve reflects the fact that average recharge during that drought was 75 percent of long-term average recharge, hence only seasonal storage would be required at withdrawal rates less than 0.75 times average recharge.

(8) Estimate potential induced streambed recharge under conditions of intensive ground-water development. Potential infiltration rates are given for each aquifer in table 4; they were calculated by applying a unit infiltration rate of 20 gallons per day per square foot to streambed areas determined chiefly from topographic maps. The potential unit infiltration rate selected seems to be reasonable in terms of present knowledge, as discussed earlier in this report. However, definitive field studies to demonstrate what effective rates of streambed recharge can be attained in the Susquehanna River basin are lacking. Furthermore, layers of poorly permeable sediments within surficial aquifers doubtless impede infiltration in some localities, and withdrawal of the maximum infiltration estimated from table 4 may not be economically practical where aquifers less than 40 feet thick border the largest streams, as previously explained. Therefore, if very conservative estimates of potential streambed recharge are deemed necessary, infiltration rates may be taken as 0.1 times the rates in table 4, or 2 times average aquifer recharge from local sources (whichever is less). If a surficial aquifer near the master stream is less than 10 feet thick, potential induced infiltration to that aquifer probably should be taken as zero.

(9) Compare the selected potential infiltration rate with available streamflow. First, determine minimum flow of the master stream (if any) at the upstream end of the aquifer. Ku and others (1975) present tables of low-flow frequency for many streams at sites where measurements have been made, and suggest procedures for estimating low flow at other sites. The 30-day 30-year low flow (the average flow for the 30 consecutive days of lowest flow occuring once in 30 years, on the average), which is numerically similar to the 7-day 10-year low flow at most sites, may be taken as an index of minimum flow. If minimum streamflow is less than the potential induced infiltration rate, reduce the estimate of infiltration accordingly.

(10) Ordinarily, add results of steps 7 and 9 to estimate total potential ground-water withdrawal. If a reduction in minimum streamflow equal to estimated potential infiltration (step 9) would not be acceptable because of a need to strictly maintain streamflow above some stipulated rate, subtract the stipulated rate from the index of minimum flow; the difference would constitute a conservative estimate of acceptable ground-water withdrawal. Aquifer testing and development might demonstrate that some water derived from local recharge and stored in the aquifer could be pumped without immediately increasing induced infiltration, but in the absence of data, such an assumption would be risky.

(11) Consider chemical quality of ground water to be withdrawn. Average values for selected chemical constituents or properties of ground water are listed in table 4 for all aquifers tapped by wells for which chemical data were available (Randall, 1972). The basinwide average frequency distribution for common chemical constituents of water from surficial and buried aquifers of various thicknesses are shown in table 3. If large amounts of recharge are obtained by induced infiltration from an adjacent stream, the chemical quality of water pumped would be intermediate between the quality of water in the stream (Ku and others, 1975) and the quality of ground water in the aquifer.

A flow diagram (fig. 17) summarizes the method of computation.

Sample Computation of Aquifer Yield

To illustrate the method of computing aquifer yield, the following sample computation has been prepared. The numbered steps correspond to those in the previous section, "method of computation." The area chosen for this example is the vicinity of Candor Village, along Catatonk Creek in the town of Candor, Tioga County (latitude 42°13', longitude 76°41', pl. 1).

(1) According to plate 1 and table 4, four aquifers have been identified near Candor Village: CATA 7-1, 8-1, 8-2, and 9-1. Surficial aquifer CATA 9-1 is thought to be less than 10 feet thick (pl. 1) and is separated from the village and the other surficial aquifers by Catatonk Creek; therefore, it is not considered further in computing aquifer yield.

(2) The only buried aquifer identified near Candor Village is CATA 8-2 (pl. 1). Recharge through the poorly permeable materials that border most of

this aquifer is estimated by multiplying aquifer area of 0.63 square miles (table 4) by 6×10^4 gallons per day per square mile, which gives 38,000 gallons per day. Sand and gravel is estimated to border 15 percent of the sides of this aquifer (table 4); thus, recharge to adjacent surficial aquifers could probably reach this aquifer to replace what is pumped from it. Storage in this aquifer will be considered in a later step, as will the recharge value already estimated.

(3) Surficial aquifers CATA 7-1 and 8-1 underlie a total of 1.4 square miles (table 4). Near Candor, the rate of recharge to surficial aquifers from precipitation averages 1.08 million gallons per day per square mile (fig. 14). Thus, recharge to these two aquifers from direct precipitation should average 1.5 million gallons per day (1.4 x 1.08).

(4) Candor is west of Owego (pl. 1), so the rate of recharge to surficial aquifers from adjacent hillsides is about 0.16 million gallons per day per mile of aquifer. Aquifer 8-1 lies beside part of aquifer 7-1 in the same segment of valley (pl. 1), so its length is not added to that of aquifer 7-1. Aquifer 7-1 is 3.2 miles long [17,000 feet (table 4), divided by 5,280 feet per mile]; multiplying by 0.16 million gallons per day per mile indicates a recharge of about 0.5 million gallons per day. If aquifer 7-1 had underlain the entire valley floor, this result would be multiplied by 2 to allow for recharge from both sides. Only the half south of Candor Village does so, however; hence this result is multiplied by 1.5 to obtain 0.75 million gallons per day as estimate of recharge from adjacent hillsides.

(5) Three tributaries to Catatonk Creek cross aquifer 7-1, as suggested by plate 1 and shown more precisely on the 7.5-minute topographic map (Candor quadrangle). The information in rows 1-3 of the following table was taken from the topographic map.

	Ketchum Hollow	Cole Brook	Unnamed brook from Candor Hill
1. Drainage area (square miles)	1.0	1.6	0.6
2. Altitude of stream, in feet, where projection of valley walls intersects stream	950	940	940
3. Channel length, in feet, measured from projection of valley walls (row 2) downstream to where gradient decreases to 1 percent	2700	1700	1600
4. Potential recharge rate to surficial aquifer 7-1, in million gallons per day (row 3 x 650 gallons per day per foot)	1.7	1.1	1.0

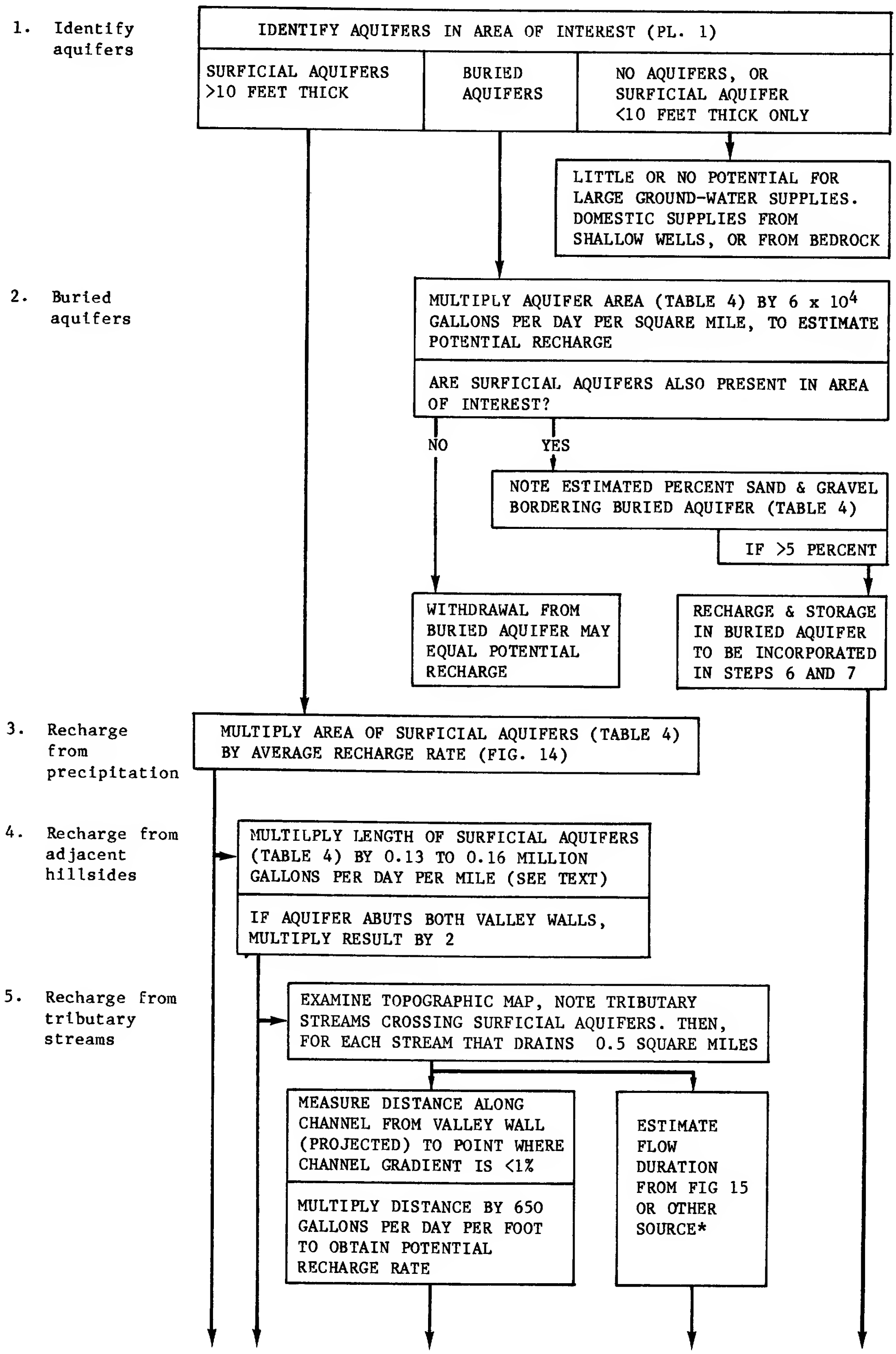
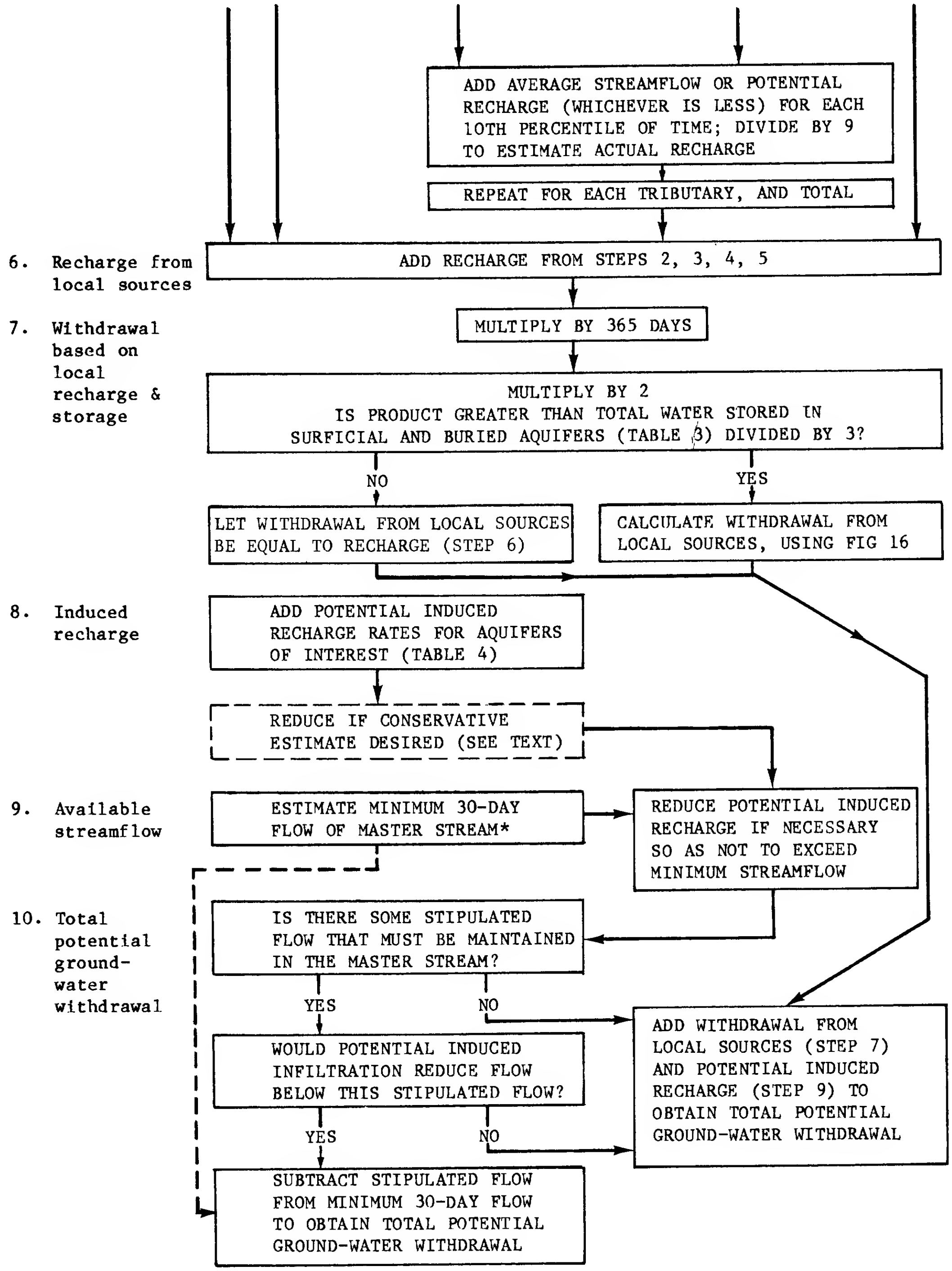


Figure 17.--Flow chart showing method of



11. Chemical quality--refer to tables 3 and 4.

*Ku and others (1975)

computing potential ground-water withdrawal.

Table 3.--Chemical quality of ground water in stratified-drift

[Modified from Hollyday, 1969. Values are in

Aquifer material and position	Aquifer thickness	Chemical characteristic category 1/	Constituent or property of water: Temperature (°C)	Silica (SiO2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)
Sand or gravel, surficial; top zero to (rarely) 50 feet below water table	Less than 10 feet	Good	7	4.5	0.04	0.01	--
		Medium	9	8.7	.11	.02	48
		Poor	10.5	19	.32*	.15*	--
	10 to 40 feet	Good	8.5	6.8	.03	.00	45
		Medium	10	7.4	.06	.01	50
		Poor	11.5	8.8	.15	.05	74
	Greater than 40 feet	Good	9.5	6.5	.03	.01	42
		Medium	10.5	8.0	.09	.02	48
		Poor	11	10	.20	.06*	56
Sand or gravel, buried beneath 50 to 200 feet of lacustrine deposits	Less than 10 feet	Good	10	5.1	.09	.01	18
		Medium	11	7.8	.30*	.05	46
		Poor	12	12	1.4*	.15*	83
	10 to 40 feet	Good	9	6.8	.03	.01	43
		Medium	10	9.2	.11	.05	54
		Poor	11.5	10	.38*	.24*	100
	Greater than 40 feet	Good	10	3.5	.05	.02	12
		Medium	11.5	4.6	.09	.05	58
		Poor	12	7.7	.18	.12*	130
Sand or gravel, buried beneath 200 feet or more of lacustrine deposits	Any	Good	--	--	.24	--	--
		Medium	--	7.8	.60*	.00	--
		Poor	--	--	5.6*	--	--

1/ Values were taken from a frequency distribution of reported chemical analyses of well water. Good, medium, and poor refer to values equaled or exceeded for 75, 50, and 25 percent of available analyses, respectively.

* Exceeds limits listed by National Academy of Sciences and National Academy of Engineering (1973).

aquifers of the Susquehanna River basin in New York

milligrams per liter except pH, temperature, and color]

Constituent or property of water												
Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Calcium & magnesium hardness as $CaCO_3$	Alkalinity	pH	Color 2/
--	--	--	150	19	8.0	--	1.6	190	97	57	7.3	--
8.5	6.0	0.8	180	28	10	0.07	2.6	250	180	140	7.5	5
--	--	--	250	35	20	--	7.0	340	220	190	7.6	--
6.0	6.6	1.1	150	25	7.8	<.05	.24	190	150	130	7.4	1
12	8.9	1.4	180	31	13	.1	1.0	240	200	150	7.6	2
19	13	1.6	230	50	22	.2	2.1	330	220	170	7.8	5
6.8	4.9	.9	160	24	8.6	<.05	.1	200	160	140	7.4	1
13	6.0	1.2	170	32	19	.1	1.2	240	220	160	7.6	2
17	11	1.4	190	44	31	.15	3.2	390	300	210	7.7	5
2.4	3.0	.4	61	12	3.3	<.05	.02	100	63	37	6.5	1
7.8	6.3	.7	110	15	11	.1	.82	190	150	98	7.2	1
20	18	1.4	210	28	16	.2	9.0	360	250	190	7.7	2
9.7	5.0	.5	150	15	7.0	.05	.12	160	120	120	7.5	2
14	8.0	1.1	180	19	12	.1	.68	210	180	140	7.7	2
19	17	1.4	210	28	24	.2	1.6	270	210	170	7.8	3
8.2	--	--	130	19	12	--	.09	160	140	140	7.4	--
12	8.1	1.2	160	27	21	.1	.5	230	210	160	7.6	3
19	--	--	220	36	29	--	2.6	340	250	190	7.7	--
--	--	--	--	--	.9	--	--	--	62	--	6.5	--
4.1	6.3	.3	76	13	2.0	<.05	.05	89	72	62	7.4	2
--	--	--	--	--	3.3	--	--	--	120	--	7.9	--

2/ Empirical units, based on comparison with diluted color standard.

Catchments of these streams contain 1 percent or less glacial or alluvial sand and gravel, as estimated by inspection of the topographic map and the county soils map (Austin, 1953). Hence long-term flow duration for each of these streams may be estimated by multiplying values from figure 15 by drainage area of each stream (row 1, table on p. 41) and by the appropriate ratio from figure 14. Results are given below; the total, 1.26 million gallons per day, represents recharge available from these three tributary streams.

	Percent flow duration									
	10	20	30	40	50	60	70	80	90	10-90 Mean
	Flow, in million gallons per day									
Ketchum Hollow	2.0*	1.1	0.64	0.41	0.25	0.14	0.07	0.035	0.017	0.48
Cole Brook	2.9*	1.5*	.93	.69	.37	.21	.10	.051	.024	.51
Unnamed brook from Candor Hill	1.1*	.6	.35	.22	.14	.08	.04	.019	.009	.27
									Total	1.26

* Greater than potential recharge rate indicated in the previous table; therefore, the potential rate is substituted in determining mean streamflow available for recharge (last column).

(6) Average recharge from local sources to aquifers near Candor Village is about 3.55 million gallons per day, the sum of results from steps 2-5 (0.04 + 1.5 + .75 + 1.26 = 3.55).

(7) To maintain during a severe drought a rate of withdrawal equal to the average recharge rate just estimated, twice the annual volume pumped would have to be available from subsurface storage, or 2.59 billion gallons (3.55 million gallons per day times 365 days times 2). Total storage in aquifers 7-1, 8-1, and 8-2 is 1.73 billion gallons (table 4), of which one-third or 0.55 billion gallons may be considered usable or available, much less than required to sustain withdrawal equal to average recharge. Therefore, a smaller rate of withdrawal that could be sustained during a severe drought from available storage is calculated by use of figure 16. First, storage is expressed as a multiple of average annual recharge.

$$\frac{\text{Total storage}}{\text{Average annual recharge}} = \frac{1.73 \text{ billion gallons}}{1.295 \text{ billion gallons}} = 1.34$$

From figure 16, the corresponding ratio of withdrawal to recharge is .76, which may be multiplied by the annual or daily rate of recharge from local sources to obtain 98.4 billion gallons per year or 3.0 million gallons per day. This is an estimate of the continuous rate of withdrawal that could be sustained from local recharge plus storage in aquifers CATA 7-1, 8-1, and 8-2 during a severe drought.

(8) Potential induced recharge from Catatonk Creek to aquifers 7-1 and 8-1 is estimated as 15.2 million gallons per day (table 4). (If circumstances were to require a very conservative estimate of induced recharge, a value as small as 1.5 million gallons per day could be arbitrarily selected.)

(9) No estimates of 30-day 30-year low flow at sites along Catatonk Creek have been published. However, the 7-day 10-year low flow was estimated to be 7.0 cubic feet per second several miles downstream at partial-record station 01-5148.00 (Ku and others, 1975, p. 105), where drainage area is 147 square miles (Wagner, 1969). Because the percentage of the drainage area covered by sand and gravel is nearly the same at both places (18.7 percent at Candor, 18.4 percent at station 01-5148.00), the 7-day 10-year low flow at Candor may be estimated by multiplying the flow at station 01-5148.00 by the drainage-area ratio

$$7.0 \times \frac{124}{147} \qquad \text{or}$$

about 6 cubic feet per second or 4 million gallons per day. By an alternative method based on equations presented by Ku and others (1975, table 4), a 7-day 10-year low flow of about 6 million gallons per day at Candor is computed as follows:

- Area of stratified drift plus alluvium upstream from Candor, delineated by interpretation of soils maps (Neely, 1965; Austin, 1953) and topographic maps and measured by planimeter = 23.2 square miles.

- Percentage area sand and gravel = 23.2/124 = 0.187 (18.7 percent)

- Mean annual runoff from basin upstream from Candor = 16.9 inches or 1.25 cubic feet per second per square mile (Ku and others, 1975, fig. 11).

- 7-day 10-year low flow = $-0.03 + (0.432)(0.187) + (0.0187)(1.25) =$ 0.074 cubic feet per second per square mile

- 124 square miles x 0.074 = 9.2 cubic feet per second or 6 million gallons per day.

The alternative estimate is probably the less accurate of the two but suggests that the first estimate may be on the low side. Thus, the rate of induced recharge that could be sustained throughout a severe drought is probably at least 4 million gallons per day.

(10) Potential ground-water withdrawal from aquifers CATA 7-1, 8-1, and 8-2 under drought conditions is about 7 million gallons per day, the sum of the estimated contribution from local sources (3 million gallons per day, step 7) and the induced recharge estimated to be available from Catatonk Creek (4 million gallons per day, step 9).

(11) Average values for certain chemical constituents or properties are as follows (from table 4):

Constituent	Aquifer CATA 7-1	Aquifer CATA 8-2
Hardness, as $CaCO_3$	175	120
Chloride	10	10
Iron	0.1	0.1

If withdrawals were to approach 7 million gallons per day, the wells near Catatonk Creek should yield water of less than 120 milligrams per liter hardness (Ku and others, 1975, p. 59-69).

Summary and commentary on sample computation.--The sample computation for the vicinity of Candor Village suggests that continuous withdrawals of about 7 million gallons per day could be sustained throughout a severe drought of several years' duration. Local recharge and storage in the aquifers would supply 3 million gallons per day, and induced infiltration from Catatonk Creek would supply the remaining 4 million gallons per day, which would probably cause the creek to go dry in that vicinity for brief periods during such a drought. During years of normal or above-normal precipitation and streamflow, withdrawals as great as 18.9 million gallons per day (3.9 from local sources, 15.2 from Catatonk Creek) could perhaps be maintained. To obtain such large yields, a few large-capacity wells would be needed near Catatonk Creek in aquifer CATA 8-1, where surficial sand and gravel is believed to be thickest. Wells of smaller capacity tapping buried aquifer 8-2 would be needed, as would wells tapping aquifer 7-1 south of Candor Village where that aquifer borders Catatonk Creek. Perhaps a few wells would be needed also in aquifer 7-1 near where Cole Brook and the brook from Ketchum Hollow begin to cross the aquifer.

Applicability of the Method

This report has presented a method of estimating aquifer yield by applying average recharge rates derived from regional studies to the dimensions and other properties of local stratified-drift aquifers. Results should be suitable for reconnaissance or preliminary planning. The computation method separately accounts for each major source or component of recharge, and for storage. With this approach, whenever new studies or specific data from a locality of interest permit a more precise estimate of some component of recharge or some aquifer property, that estimate may be substituted. The method resembles techniques used in earlier studies (see references under "General Approach," p. 32) and could be applied to other basins in the Northeast if appropriate data could be obtained.

A principal limitation on the reliability of aquifer yields computed by this method is the lack of adequate field data, particularly data on effective streambed hydraulic conductivity and aquifer geometry. As of 1970, there were only a few valley reaches in the Susquehanna River basin or elsewhere in the Appalachian Plateau of New York where localized groundwater pumpage was quantitatively significant in comparison with flow of the master stream. In none of these reaches had streamflow losses been measured. Measurement of losses to induced infiltration under varied conditions of river and subsurface hydraulic head would be necessary to compute effective hydraulic conductivity of the streambed. The concept of streambed conductivity may prove to depend less on the streambed itself than on aquifer materials immediately beneath. Research is needed to (1) define the range of effective hydraulic conductivity values for the beds of major streams in the Susquehanna River basin, and (2) discern the factors controlling whatever variability may be found. Until such research is undertaken, estimates based on measurements in comparable alluvial channels elsewhere in the United States must suffice.

Where well or test-boring records are numerous (fig. 2; see Randall, 1972 for more detail), aquifer geometry is moderately well defined, but where subsurface data are sparse, the aquifer dimensions listed in table 4 are largely inferences from experience in other localities of similar land forms. As development proceeds in areas where data are sparse, records of new wells and test borings will become available and could be used to revise the interpretations of aquifer geometry in table 4 and plate 1.

Despite the limitations in data, the method of aquifer evaluation outlined in preceding sections is thought to generally yield conservative results, inasmuch as several factors that would increase estimates of yield were disregarded. These factors are discussed below:

(1) *Flow from adjacent aquifers.*--Each surficial aquifer was treated as an isolated unit so that estimates for adjacent aquifers could be summed to obtain total yield available from a reach of valley. If any one aquifer or group of aquifers were developed, however, the yield actually obtained would include lateral inflow from adjacent aquifers, which could be appreciable.

(2) *High stages in streams.*--The infiltration rate of 20 gallons per day per square foot proposed by Moore and Jenkins (1966) was intended to apply to streams having 1 foot depth of water or less. All master streams in the Susquehanna River basin are deeper than 1 foot occasionally, and many are deeper than 1 foot continuously. Hence, if streambeds in the Susquehanna basin are similar to those studied by Moore and Jenkins, larger infiltration rates may be possible, especially during seasonal periods of high river stage.

(3) *Reuse of water.*--For purposes of computation, induced recharge is treated as limited by a statistical measure of low streamflow based on historical records. This procedure does not allow for the likelihood that most of the water withdrawn from an aquifer would be returned to the master stream, if not directly to the aquifer. Although used water is ordinarily somewhat elevated in temperature and(or) in concentration of various dissolved constituents, percolation through earth materials

following ground disposal or induced infiltration may render it suitable for reuse without further treatment. As pointed out by MacNish and others (1969, p. 21), total water available in any locality could be greatly increased by reuse.

The more that is known about an aquifer, the better its yield can be estimated. One advantage of developing ground-water supplies, as compared with surface-water supplies, is that commonly the ultimate or maximum yield of a proposed well field need not be accurately estimated before construction begins, and phased development and financing can keep pace with gradual increases in water demand. It is often possible to construct wells to meet initial demand, obtain records of water-level response to pumping over several months or years of operation, then use these records to decide whether and where additional water may be withdrawn. Aquifer yield may be estimated more precisely under such conditions by techniques more site specific and sophisticated than the method outlined in this report. For example, yield in a few small localities in the Susquehanna River basin has been estimated by use of equations that describe ground-water flow (Hazen and Sawyer, 1965), flow nets and pumpage records (Randall, 1977), and a digital computer model (Cosner and Harsh, 1978).

Several digital computer codes have been developed to simulate ground-water flow; if the dimensions and properties of a particular aquifer are known and incorporated in a code, the resulting model can be used to predict water-level response to any postulated distribution and magnitude of pumping. One such code was developed by Pinder and Bredehoeft (1968) and subsequently improved by Trescott and others (1976). As part of the present study, a computer program was written to adapt this code to receive and use aquifer dimensions and properties in the format compiled by AQUILIST. However, such application of digital modeling techniques can be justified only on an experimental basis at present. Digital models are normally calibrated against historical records of water levels, pumpage, and(or) river stage before being used for prediction, but such records were unavailable in 1970 for the vast majority of the aquifers tabulated in AQUILIST.

Minimizing Effects of Ground-Water Development on Streamflow

MacNish and others (1969), in making a preliminary appraisal of water resources in three urban areas in the Susquehanna River basin, concluded that in each area, aquifer recharge potentially available by induced infiltration from major streams far exceeded that from local sources. Computations by the method outlined in this report should lead to similar conclusions for most valley reaches. Thus, pumping large amounts of water continuously from stratified-drift aquifers would reduce streamflow much as if the water were being withdrawn directly from the stream, and aquifers would function chiefly as natural filters to remove the turbidity and microorganisms present in surface water. If the water is not returned to the stream, or is returned as wastewater requiring dilution, streamflow depletion may become a problem.

In some situations, however, large withdrawals of ground water might be needed only for a few weeks or months in late summer or autumn to provide supplemental irrigation of crops (Young and Bredehoeft, 1972, p. 534), to

augment low streamflow downstream (Backshall and others, 1972), or to help with industrial cooling when stream temperatures are excessively high (Randall, 1977, p. 28). In some localities, it would be possible to meet short-term demands and still minimize depletion of streamflow during critical low-flow periods by pumping from buried aquifers, broad surficial aquifers at sites near the valley sides, or surficial aquifers where barriers of lake beds, till, or bedrock restrict movement of water from the master stream into the aquifer. Under such circumstances, water pumped during the period of need would come largely from storage in the aquifer and would be replaced by induced recharge over succeeding months, when streamflow is greater. A preliminary selection of aquifers that have small potential for induced infiltration in proportion to their area may be made from table 4 and plate 1. Randall (1977, p. 33) mentions a few localities where impermeable barriers prevent water movement between river and aquifer; the corresponding numbered aquifers in table 4 are listed below. However, quantitative evaluation of the effect that brief, large withdrawals from aquifers would have on streamflow is beyond the scope of this report.

Locality	Aquifers
Binghamton	SUSQ 36-1, 36-3, 37-1, 37-2, 37-3, 38-1, 39-1, 39-2
Kattellville	KATT 0-2, 1-2, 2-1, CHEN 8-3
Big Flats	BIGF 3-1, 3-4, 3-2
Cortland	OTTR 0-1, 0-2, 1-1, 1-2, 2-1
Sherburne, Smyrna	CHEN 51-3, 52-3, 54-3

SUMMARY

The most productive aquifers in the Susquehanna River basin of New York are deposits of sand and gravel included within the stratified glacial drift beneath the floors of major valleys. Such aquifers occur just below land surface in most valleys, and locally reach thicknesses well over 40 feet. Depth to bedrock is as great as 500 feet in a few valley reaches, but increased thickness of stratified drift generally means more clay, silt, and fine sand rather than thicker aquifer materials. Sand and gravel aquifers are also found buried beneath fine-grained sediments in many broad valleys, although well yields and water quality are commonly inferior to those obtained from thick surficial aquifers.

A generalized, qualitative view of the arrangement of aquifers and non-water-yielding sediments within the valley fill is provided by figures 4-10 for all major valleys of the basin. Quantitative estimates of depth, thickness, extent, and water-storage capacity of these aquifers are provided in plate 1 and table 4; the detail and reliability of these estimates varies

with the density of subsurface information available. One approach to evaluating aquifer yield is to estimate and combine the amounts of water available from each potential source of recharge and from storage; a method of so doing is explained in detail in the text and summarized in figure 17. Because new information may allow reinterpretation of aquifer shape and other properties in particular localities, the format in which aquifer properties were compiled is outlined in the text.

The largest potential source of recharge to most stratified-drift aquifers in the Susquehanna River basin is induced infiltration of water from major streams. Research is needed to determine the magnitude of streambed infiltration rates and the factors controlling variation in those rates in the Susquehanna River basin, so that preliminary estimates of potential recharge can be made with more confidence prior to extensive ground-water development or site testing. Although it is generally impossible to pump water steadily for many months from stratified-drift aquifers without depleting streamflow by a comparable amount, aquifers in a few localities are believed to have small potential for induced infiltration, in which case pumping during critical periods of low streamflow may have negligible effect on the streams.

REFERENCES CITED

Austin, Morris E., 1953, Soil survey of Tioga County, New York: U.S. Department of Agriculture, Soil Conservation Service ser. 1939, no. 20.

Backshall, W. F., Downing, R. A., and Law, F. M., 1972, Great Ouse ground-water study: Water and Water Engineering, June 1972, p. 215.

Cervione, M. A., Jr., Mazzaferro, D. L., and Melvin, R. L., 1972, Water resources inventory of Connecticut, part 6, upper Housatonic River basin: Connecticut Department of Environmental Protection, Water Resources Bulletin 21, 84 p.

Coates, D. R., 1966, Discussion of K. M. Clayton "Glacial erosion in the Finger Lakes region (New York, U.S.A.)": Zeitschrift fur Geomorphologie, (new ser.), v. 10, no. 4, p. 469-474.

Cohen, Philip, Franke, O. L., and Foxworthy, B. L., 1968, An atlas of Long Island's water resources: New York Water Resources Commission Bulletin 62, 117 p.

Cosner, O. J., and Harsh, J. F., 1978, Digital-model simulation of the glacial-outwash aquifer, Otter Creek-Dry Creek basin, Cortland County, New York: U.S. Geological Survey Water-Resources Investigations 78-71, 34 p.

Crain, L. J., 1974, Ground-water resources of the Western Oswego River basin, New York: New York Department of Environmental Conservation Basin Planning Report ORB-5, 137 p.

Cressy, G. B., 1966, Land Forms, in Thompson, J. H., ed., 1966, Geography of New York: Syracuse, N.Y., Syracuse University Press, 543 p.

Hazen and Sawyer, 1965, Report on West Hudson Street aquifer, Elmira, New York: New York City, unpublished report to Elmira Water Board, Elmira, N.Y., 30 p.

Hollyday, E. F., 1969, An appraisal of the ground-water resources of the Susquehanna River basin in New York: U.S. Geological Survey open-file report, 52 p.

Kantrowitz, I. H., 1970, Ground-water resources in the eastern Oswego River basin, New York: New York State Conservation Department, Basin Planning Report ORB-2, 129 p.

Kirkland, James, 1970, Deglaciation of the eastern Finger Lakes region, in Heaslip, W. G., (ed.), 1970, Field trip guidebook, 42nd annual meeting: Cortland, N.Y., New York State Geological Association, 145 p.

Ku, Henry F. H., Randall, A. D., and MacNish, R. D., 1975, Streamflow in the New York part of the Susquehanna River basin: New York Department of Environmental Conservation, Bulletin 71, 130 p.

La Sala, A. M., 1968, Ground-water resources of the Erie-Niagara basin, New York: New York State Conservation Department, Basin Planning Report ENB-3, 114 p.

MacNish, R. D., Randall, A. D., and Ku, H. F. H., 1969, Water availability in urban areas of the Susquehanna River basin--a preliminary appraisal: New York State Department of Conservation, Report of Investigations 7, 24 p.

Moore, J. E., and Jenkins, C. T., 1966, An evaluation of the effect of ground-water pumpage on the infiltration rate of a semipervious streambed: Water Resources Research, v. 2, no. 4, p. 691-696.

National Academy of Sciences and National Academy of Engineering, 1973 [1974], Water Quality Criteria 1972: U.S. Government Printing Office, 594 p.

Neely, John A., 1965, Soil survey of Tompkins County, New York: U.S. Department of Agriculture, Soil Conservation Service, ser. 1961, no. 25.

Pinder, G. F., and Bredehoeft, J. D., 1968, Application of the digital computer for aquifer evaluation: Water Resources Research, v. 4, no. 5, p. 1069.

Randall, A. D., Thomas, M. P., Thomas, C. E., and Baker, J. A., 1966, Water resources inventory of Connecticut, part 1, Quinebaug River basin: Connecticut Water Resources Bulletin 8, 102 p.

REFERENCES CITED (continued)

Randall, A. D., 1972, Records of wells and test borings in the Susquehanna River basin: New York State Department of Environmental Conservation, Bulletin 69, 92 p.

_______, 1977, The Clinton Street-Ballpark aquifer in Binghamton and Johnson City, N.Y.: New York State Department of Environmental Conservation, Bulletin 73, 87 p.

_______, 1978, Infiltration from tributary streams in the Susquehanna River basin, New York: U.S. Geological Survey Journal of Research, v. 6, no. 3, p. 285-297.

Todd, D. K., 1959, Ground-water hydrology: New York, John Wiley, 336 p.

Trescott, P. C., Pinder, G. F., and Larson, S. P., 1976, Finite-difference model for aquifer simulation in two dimensions with result of numerical experiments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 7, Chapter C1., 116 p.

Wagner, L. A., 1969, Named streams in the Susquehanna River basin (above Chemung River): Albany, N.Y., U.S. Geological Survey, unpublished report, New York, drainage area data, list G.

Wetterhall, W. S., 1959, The ground-water resources of Chemung County: New York State Water Power and Control Commission Bulletin GW-40, 58 p.

Young, R. A., and Bredehoeft, J. A., 1972, Digital computer simulation for solving management problems of conjunctive ground-water and surface water systems: Water Resources Research, v. 8, no. 3, p. 533-556.

TABLE 4

AQUILIST tabulation of aquifers in Susquehanna River basin, New York. (Aquifer names are given in table 2; locations are shown on plate 1.)

Table 4.--AQUILIST tabulation of aquifers

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter): Hardness (as $CaCO_3$)	Chemical data (milligrams per liter): Chloride	Chemical data (milligrams per liter): Iron
BENT 14	13000.	0.23	0.33	5.40	72.	100.	--	--	--	--
BENT 21	25000.	1.35	0.56	54.00	10.	100.	--	--	--	--
BENT 22	25000.	1.26	2.09	0.0	10.	100.	--	--	--	--
BENT 71	27000.	0.97	1.41	46.40	13.	100.	--	154.	--	--
BIGF 31	28000.	4.22	3.52	8.40	39.	1000.	463.	250.	15.	0.03
BIGF 32	11000.	1.66	1.38	0.0	4.	100.	--	198.	5.	0.03
BIGF 34	13000.	0.70	1.46	0.60	72.	100.	--	236.	9.	0.02
BUTR 21	3000.	0.09	0.12	0.0	80.	100.	--	--	--	--
BUTR 23	3000.	0.52	3.08	3.60	2.	100.	--	--	--	--
BUTR 51	21000.	2.41	0.97	34.02	17.	100.	--	--	--	--
BUTR 53	3200.	0.46	2.82	0.91	1.	100.	--	--	--	--
BUTR 54	4100.	0.69	4.28	1.29	1.	100.	--	--	--	--
BUTR 62	62000.	6.23	3.76	0.0	17.	100.	--	--	--	--
BUTR 73	3000.	0.32	1.82	0.74	3.	100.	--	--	--	--
BUTR 83	2800.	0.30	1.23	0.65	2.	100.	--	--	--	--
BUTR 123	4200.	0.60	2.63	2.10	26.	100.	--	--	--	--
BUTR 133	5200.	0.65	2.15	1.44	31.	100.	--	--	--	--
BUTR 161	61000.	4.81	10.54	39.60	0.	100.	--	--	--	--
BUTR 251	9000.	0.26	0.13	3.60	0.	100.	--	--	--	--
CACA 11	11000.	0.36	0.15	11.50	8.	100.	--	--	--	--
CACA 31	7500.	0.19	0.31	2.00	27.	100.	--	--	--	--
CACA 54	900.	0.19	0.44	0.75	54.	100.	--	--	--	--
CACA 61	32000.	1.72	4.31	12.50	62.	100.	--	200.	6.	0.03
CACA 64	10000.	0.32	0.40	2.00	87.	100.	--	205.	--	0.50
CANI 21	25000.	2.24	2.57	84.00	20.	100.	310.	140.	15.	0.12
CANI 43	18000.	0.97	0.61	25.90	92.	100.	--	--	--	--
CANI 171	124000.	5.78	7.84	324.00	8.	100.	--	--	--	--
CANI 272	4600.	0.25	0.26	0.0	25.	100.	--	--	--	--
CANI 301	33000.	2.96	4.01	51.80	26.	100.	--	310.	40.	0.20
CANI 302	33000.	2.72	4.54	0.0	30.	100.	--	--	--	--
CANI 341	23000.	0.91	2.27	19.60	38.	100.	442.	190.	13.	0.03
CANI 343	1500.	0.32	0.94	1.50	89.	100.	--	--	--	--
CANI 371	26000.	3.73	5.45	26.00	57.	100.	488.	215.	12.	0.07
CANI 372	26000.	3.73	4.67	0.0	37.	100.	--	--	--	--
CANI 394	22000.	3.95	4.94	2.80	91.	100.	--	--	--	--
CATA 11	10500.	0.56	1.41	10.50	30.	100.	--	--	--	--
CATA 41	21000.	1.21	0.88	30.40	26.	100.	--	--	--	--
CATA 42	21000.	1.13	1.30	0.0	25.	100.	--	132.	0.	0.06
CATA 61	9000.	0.39	0.97	9.60	40.	100.	--	--	--	--
CATA 71	17000.	1.22	0.81	7.20	37.	100.	--	175.	10.	0.10
CATA 81	4000.	0.19	0.39	8.00	51.	100.	--	--	--	--
CATA 82	11000.	0.63	0.53	0.0	15.	100.	--	120.	10.	0.10
CATA 91	11000.	0.59	0.19	14.00	56.	100.	--	--	--	--
CATA 113	700.	0.23	0.39	3.20	95.	100.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
CATA 131	41000.	4.71	5.40	43.00	23.	100.	--	156.	5.	0.04
CATA 163	6500.	0.54	0.67	0.70	59.	100.	--	--	--	--
CATA 191	18000.	2.39	4.73	4.50	25.	100000.	--	--	--	--
CATA 201	2300.	0.21	0.72	0.20	100.	100000.	--	--	--	--
CAYU 11	7000.	0.75	0.94	11.20	81.	100.	--	280.	29.	0.16
CAYU 13	1500.	0.43	0.61	0.0	13.	100.	--	150.	5.	0.05
CAYU 81	64000.	2.53	3.16	79.20	7.	100.	--	--	--	--
CAYU 181	29000.	1.77	2.40	32.45	13.	100.	--	--	--	--
CAYU 204	6000.	0.28	0.23	2.40	70.	100.	--	--	--	--
CAYU 231	29000.	1.14	1.55	26.55	9.	100.	--	--	--	--
CAYU 292	2800.	0.12	0.15	0.0	85.	100.	--	--	--	--
CAYU 312	7000.	0.38	0.47	0.0	91.	100.	--	--	--	--
CAYU 313	1000.	0.68	0.57	0.10	3.	100.	--	--	--	--
CAYU 314	1000.	0.68	0.57	0.40	50.	100.	--	--	--	--
CHAR 11	12500.	0.99	2.36	45.60	32.	100.	--	--	--	--
CHAR 12	4000.	0.39	0.62	0.0	0.	100.	--	--	--	--
CHAR 21	4500.	0.39	2.79	11.00	0.	100.	--	--	--	--
CHAR 52	25000.	2.15	4.40	0.0	18.	100.	--	--	--	--
CHAR 54	5000.	0.18	0.70	1.50	9.	100.	--	--	--	--
CHAR 71	5300.	0.53	0.93	10.08	0.	100.	--	--	--	--
CHAR 92	13000.	1.03	2.25	0.0	6.	100.	--	--	--	--
CHAR 131	38000.	2.04	4.22	29.25	1.	100.	--	--	--	--
CHAR 151	8000.	0.43	0.48	6.00	10.	100.	--	--	--	--
CHEM 31	8000.	0.57	0.48	60.00	60.	100.	--	--	--	--
CHEM 44	700.	0.23	0.28	0.36	96.	100.	--	--	--	--
CHEM 52	30000.	2.15	3.30	0.0	34.	100.	--	--	--	--
CHEM 54	4000.	1.72	0.54	1.00	14.	100.	--	--	--	--
CHEM 61	26000.	2.80	0.93	196.00	51.	100.	--	--	--	--
CHEM 71	3000.	0.16	0.42	21.00	77.	100.	--	--	--	--
CHEM 81	18000.	0.52	0.80	0.0	60.	100.	--	--	--	--
CHEM 91	8000.	1.00	0.73	41.60	72.	1000.	--	--	--	--
CHEM 93	1000.	0.39	0.08	0.0	96.	100.	--	--	--	--
CHEM 104	700.	0.23	0.19	0.14	98.	100.	--	138.	--	--
CHEM 111	21000.	0.90	2.53	84.00	43.	100.	--	--	--	--
CHEM 112	2500.	0.18	0.30	0.0	89.	100.	--	--	--	--
CHEM 114	2000.	1.29	0.43	1.20	5.	100.	--	--	--	--
CHEM 123	5500.	0.30	0.12	3.00	79.	100.	--	--	--	--
CHEM 141	43000.	10.80	9.01	402.00	46.	1000.	--	240.	20.	0.08
CHEM 142	13000.	0.93	1.67	0.0	18.	100.	--	--	--	--
CHEM 161	11000.	0.39	1.32	0.0	20.	100.	--	--	--	--
CHEM 181	10000.	1.61	3.97	70.00	66.	100.	0.	240.	29.	0.09
CHEM 182	3000.	0.32	0.47	0.0	60.	100.	--	425.	1200.	1.30
CHEM 204	1000.	0.36	0.37	0.0	95.	100.	--	--	--	--
CHEM 211	22000.	1.42	3.67	161.00	17.	100.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter): Hardness (as $CaCO_3$)	Chemical data (milligrams per liter): Chloride	Chemical data (milligrams per liter): Iron
CHEM 242	3600.	0.26	0.38	0.0	35.	100.	--	--	--	--
CHEM 261	25000.	3.77	3.14	0.0	44.	1000.	--	--	--	--
CHEM 292	4000.	0.26	0.43	0.0	30.	100.	--	--	--	--
CHEM 311	28000.	3.52	9.53	217.00	24.	100.	440.	210.	35.	0.10
CHEM 313	2400.	0.95	0.99	1.60	91.	100.	--	--	--	--
CHEM 322	2800.	0.05	0.05	0.0	25.	100.	--	220.	34.	0.60
CHEM 341	8000.	0.57	1.94	64.00	40.	100.	--	190.	30.	0.06
CHEM 352	10000.	0.93	1.85	0.0	60.	100.	--	205.	20.	0.06
CHEM 354	3000.	1.08	0.90	1.80	90.	100.	--	--	20.	0.05
CHEN 01	10800.	1.36	0.85	48.00	50.	1000.	--	315.	60.	--
CHEN 12	6200.	0.22	0.28	0.0	43.	100.	--	--	--	--
CHEN 21	24500.	1.32	5.77	122.50	41.	100.	--	245.	25.	0.08
CHEN 22	9000.	0.65	2.42	0.0	41.	100.	--	185.	11.	0.08
CHEN 31	18000.	0.65	0.40	0.60	52.	100.	--	--	--	--
CHEN 32	17000.	0.30	0.38	0.0	50.	100.	--	--	--	--
CHEN 41	19000.	0.55	0.40	72.00	33.	100.	--	--	--	--
CHEN 61	3000.	0.05	0.12	19.80	13.	100.	--	--	--	--
CHEN 81	12000.	0.52	0.41	81.18	13.	100.	--	120.	1.	0.15
CHEN 82	1500.	0.17	0.18	0.0	16.	100.	--	--	--	--
CHEN 83	3200.	0.37	0.31	0.0	45.	100.	--	--	--	--
CHEN 91	5000.	0.81	1.35	19.80	47.	1000.	--	--	--	--
CHEN 111	14000.	1.76	5.50	78.40	11.	100.	--	--	--	--
CHEN 143	800.	0.20	0.38	0.16	52.	100.	--	--	--	--
CHEN 153	2000.	0.22	0.99	0.30	4.	100.	--	--	--	--
CHEN 171	8000.	1.00	3.70	47.10	36.	1000.	--	--	--	--
CHEN 172	44000.	3.16	1.97	0.0	76.	100.	--	--	--	--
CHEN 184	12000.	0.86	4.71	1.44	14.	100.	--	--	--	--
CHEN 193	1100.	0.39	1.73	0.30	87.	100.	--	--	--	--
CHEN 214	2000.	1.15	5.75	1.00	91.	100.	--	--	--	--
CHEN 223	2000.	0.25	1.20	3.76	82.	100.	--	--	--	--
CHEN 234	10000.	0.72	2.69	4.60	17.	100.	--	--	--	--
CHEN 243	3000.	0.43	0.90	1.00	79.	100.	--	--	--	--
CHEN 261	41200.	5.91	21.58	137.10	53.	100.	--	--	--	--
CHEN 273	1800.	1.03	4.09	2.08	4.	100.	--	--	--	--
CHEN 281	12000.	1.08	4.85	40.80	58.	100.	--	--	--	--
CHEN 282	15700.	1.13	1.34	0.0	73.	1000.	--	--	--	--
CHEN 293	6000.	0.22	1.12	4.15	30.	100.	--	--	--	--
CHEN 301	20500.	2.21	9.20	88.20	45.	1000.	--	--	--	--
CHEN 313	2700.	0.46	2.44	14.00	11.	100.	--	--	--	--
CHEN 323	1200.	0.37	1.81	0.64	4.	100.	--	--	--	--
CHEN 324	1200.	0.37	2.10	0.69	4.	100.	--	--	--	--
CHEN 331	15700.	1.24	5.68	51.70	69.	100.	--	--	--	--
CHEN 332	17000.	1.22	9.41	0.0	100.	100.	--	--	--	--
CHEN 343	3500.	0.82	4.55	1.20	11.	100.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter)		
								Hardness (as $CaCO_3$)	Chloride	Iron
CHEN 344	1200.	0.43	2.41	0.64	3.	100.	--	--	--	--
CHEN 361	13000.	1.17	12.08	33.00	0.	100.	--	--	--	--
CHEN 393	3000.	0.54	3.58	1.24	8.	100.	--	--	--	--
CHEN 401	37000.	2.39	1.54	102.00	31.	100.	--	--	--	--
CHEN 402	39000.	2.94	10.17	0.0	30.	1.	--	--	--	--
CHEN 404	2500.	0.22	0.97	0.56	3.	100.	--	--	--	--
CHEN 411	3000.	0.11	0.27	6.00	15.	1000.	--	--	--	--
CHEN 413	12000.	0.86	2.99	16.80	22.	100.	--	--	--	--
CHEN 424	2000.	0.14	0.58	0.42	4.	100.	--	--	--	--
CHEN 434	8000.	0.32	1.56	2.09	18.	100.	--	--	--	--
CHEN 454	2200.	0.20	0.92	0.42	3.	100.	--	--	--	--
CHEN 471	37000.	3.72	2.28	73.44	21.	100.	--	--	--	--
CHEN 473	3500.	0.44	2.26	1.22	9.	100.	--	--	--	--
CHEN 492	33000.	2.49	1.52	0.0	24.	100.	--	--	--	--
CHEN 504	3000.	0.32	1.48	0.34	8.	100.	--	--	--	--
CHEN 513	21000.	1.96	3.20	1.60	7.	100.	--	--	--	--
CHEN 514	3000.	0.32	1.51	0.56	8.	100.	--	--	--	--
CHEN 523	10000.	0.72	2.29	1.22	49.	100.	--	--	--	--
CHEN 531	15000.	1.08	0.45	16.50	0.	100.	--	--	--	--
CHEN 543	17000.	1.22	3.82	3.52	13.	100.	--	--	--	--
CHEN 544	14000.	1.91	5.77	6.80	4.	100.	--	--	--	--
CHEN 572	50000.	7.53	10.74	0.0	22.	100.	--	--	--	--
CHEN 591	35000.	5.65	5.13	85.05	22.	100.	--	--	--	--
CHEN 681	68000.	4.88	12.90	23.68	1.	100.	--	--	--	--
CHER 12	23000.	2.06	3.44	0.0	0.	100.	--	--	--	--
CHER 21	10000.	0.90	1.97	22.10	0.	100.	--	--	--	--
CHER 51	8500.	0.98	1.18	15.60	0.	1000.	--	--	--	--
CHER 91	5000.	0.54	0.65	9.00	0.	100.	--	--	--	--
CHER 102	46200.	4.97	8.67	0.0	4.	100.	--	--	--	--
CHER 113	3000.	0.27	1.08	0.56	3.	100.	--	--	--	--
CHER 134	8000.	0.43	0.26	15.99	0.	100.	--	--	--	--
CHER 151	6000.	0.13	0.10	2.52	0.	100.	--	--	--	--
CHIN 33	1500.	0.19	0.15	0.30	10.	100.	--	--	--	--
CHIN 61	17000.	0.43	0.27	3.60	2.	100.	--	--	--	--
COHC 12	14000.	0.80	1.17	0.0	24.	100.	--	--	--	--
COHC 41	44000.	5.52	8.06	23.50	12.	100.	336.	124.	13.	0.50
COHC 73	4000.	0.19	0.08	0.80	75.	100.	--	--	--	--
COHC 101	19000.	2.73	2.27	48.00	32.	100.	--	--	--	--
COHC 102	19000.	2.59	5.40	0.0	8.	100.	--	--	--	--
COHC 141	16000.	2.58	8.62	26.40	30.	100.	--	--	--	--
COHC 152	2000.	0.18	0.11	0.0	100.	100.	--	--	--	--
COHC 153	8000.	0.52	0.43	2.55	82.	100.	--	--	--	--
COHC 161	12000.	1.94	1.62	35.20	67.	100.	--	--	--	--
COHC 162	14000.	2.26	1.89	0.0	24.	100.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
COHC 164	8000.	1.72	3.59	0.0	40.	100.	--	--	--	--
COHC 172	5500.	0.39	0.82	0.0	13.	100.	383.	183.	16.	0.06
COHC 181	14800.	1.86	6.20	33.66	43.	100.	357.	220.	7.	0.06
COHC 231	39000.	4.90	4.08	76.80	22.	100.	--	--	--	--
COHC 232	39000.	4.62	11.55	0.0	22.	100.	--	--	--	--
COHC 311	40000.	5.74	19.15	57.60	14.	100.	--	190.	10.	0.10
COHC 352	6000.	0.54	0.67	0.0	100.	100.	--	--	--	--
COHC 381	33000.	6.27	7.20	18.40	29.	100.	410.	190.	13.	0.10
CORN 12	6000.	0.65	1.21	0.0	22.	100.	--	--	--	--
DUDL 11	16000.	0.29	0.14	4.95	10.	100.	--	--	--	--
DUDL 41	21000.	0.38	0.27	0.16	46.	100.	--	--	--	--
DUDL 52	18000.	0.26	0.22	0.0	50.	100.	--	--	--	--
ELK 31	29500.	1.38	5.08	11.16	3.	100.	--	--	--	--
ELMB 13	300.	0.04	0.13	0.04	49.	100.	--	--	--	--
ELMB 12	10300.	0.74	1.00	0.0	26.	100.	--	--	--	--
ETIO 02	6500.	0.21	0.16	0.0	56.	100.	--	--	--	--
ETIO 11	8000.	0.95	1.56	14.00	29.	100.	--	--	--	--
ETIO 31	13500.	1.11	1.63	18.00	17.	100.	--	--	--	--
ETIO 62	15000.	0.86	0.72	0.0	34.	100.	--	--	--	--
ETIO 71	28000.	2.31	3.85	34.00	21.	100.	--	--	--	--
ETIO 92	12000.	0.65	0.81	0.0	68.	100.	--	--	--	--
ETIO 101	12000.	0.99	1.03	11.60	27.	100.	--	152.	30.	0.15
ETIO 142	12000.	0.86	0.54	0.0	7.	100.	--	--	--	--
ETIO 151	20000.	2.51	2.09	13.80	15.	100.	--	--	--	--
ETIO 194	18000.	0.71	0.37	3.90	57.	100.	--	--	--	--
ETIO 201	17000.	1.83	0.38	4.80	17.	100.	--	--	--	--
ETIO 241	7000.	0.63	0.39	2.40	15.	100.	--	--	--	--
FIVE 11	5000.	0.50	0.42	6.24	72.	100.	--	--	--	0.0
FIVE 12	9000.	0.65	1.21	0.0	78.	100.	--	--	--	--
FIVE 31	16000.	1.38	1.15	19.20	54.	100.	--	--	--	--
FIVE 32	13000.	0.47	0.58	0.0	73.	100.	--	--	--	--
FIVE 33	800.	0.43	0.72	0.48	3.	100.	--	--	--	--
FIVE 54	800.	0.01	0.02	0.28	57.	100.	--	--	--	--
FIVE 73	1000.	0.77	1.29	0.80	42.	100.	--	--	--	--
FIVE 74	600.	0.18	0.29	0.06	42.	100.	--	--	--	--
FIVE 81	4100.	0.26	0.17	0.0	100.	100.	--	--	--	--
FIVE 94	1400.	0.22	0.32	0.0	88.	100.	--	--	--	--
FIVE 102	7000.	0.48	0.40	0.0	100.	100.	--	--	--	--
FIVE 104	5000.	0.18	0.17	1.00	54.	100.	--	--	--	--
FIVE 111	13500.	1.16	0.97	6.00	58.	100.	--	--	--	--
FIVE 112	10000.	0.54	0.67	0.0	43.	100.	--	190.	25.	0.40
FIVE 132	4000.	0.20	0.21	0.0	63.	100.	--	--	--	--
FIVE 141	21000.	0.75	0.63	5.40	31.	100.	--	--	--	--
FLY 11	13000.	1.03	3.01	4.26	12.	100.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
GENE 111	20000.	0.36	0.15	8.40	17.	100.	--	--	--	--
GENE 82	18000.	0.52	0.38	0.0	34.	100.	--	--	--	--
GENE 71	6000.	0.13	0.13	0.45	43.	100.	--	--	--	--
GENE 42	7500.	0.27	0.45	0.0	28.	100.	--	--	--	--
GENE 01	8500.	0.43	0.89	11.40	18.	100.	--	--	--	--
KATT 21	12500.	0.90	3.09	0.0	35.	100.	--	190.	13.	0.07
KATT 12	7500.	0.16	0.13	0.0	5.	100.	--	--	--	--
KATT 02	6500.	0.30	0.51	0.0	58.	100.	--	--	--	--
LABR 11	5000.	0.32	0.54	1.10	13.	100.	--	--	--	--
LABR 22	15000.	0.65	0.54	0.0	6.	100.	--	--	--	--
LABR 34	800.	0.14	0.12	0.05	4.	100.	--	--	--	--
LABR 51	1500.	0.13	0.11	0.0	15.	100.	--	--	--	--
MEAD 22	20000.	1.15	1.44	0.0	36.	100.	--	--	--	0.0
MEAD 61	64000.	4.36	5.46	56.00	30.	100.	--	68.	--	--
MEAD 82	9000.	0.65	0.81	0.0	38.	100.	--	--	--	--
MUD 11	11000.	1.38	1.15	15.00	39.	100.	--	74.	5.	0.10
MUD 92	4000.	0.43	0.90	0.0	86.	100.	--	--	--	--
MUD 102	6000.	0.43	0.90	0.0	81.	100.	--	--	--	--
MUD 104	3600.	1.55	2.23	0.12	86.	100.	--	--	--	--
MUD 114	15000.	0.65	0.81	6.20	93.	100.	--	--	--	--
MUD 132	4500.	0.32	0.81	0.0	100.	100.	--	--	--	--
MUDC 11	14000.	0.70	2.05	11.60	5.	100.	--	--	--	--
MUDC 31	10500.	0.19	0.31	0.05	7.	100.	--	--	--	--
MUDC 52	28000.	1.91	1.99	0.0	7.	100.	--	--	--	--
MUDC 84	16000.	0.52	0.32	3.30	5.	100.	--	--	--	--
MUDC 91	13000.	0.65	0.68	5.80	6.	100.	--	--	--	--
NANT 02	7000.	0.18	0.24	0.0	57.	100.	--	--	--	--
NANT 11	12500.	0.31	0.92	7.50	22.	100.	--	250.	30.	0.20
NANT 42	4500.	0.15	0.12	0.0	17.	100.	--	--	--	--
NANT 62	16000.	0.29	0.42	0.0	6.	100.	--	--	8.	--
NANT 81	16000.	1.03	1.40	16.00	14.	100.	--	96.	4.	0.25
NANT 121	25000.	0.72	0.90	16.20	10.	100.	--	--	--	--
NEIL 101	8000.	0.75	1.87	0.0	70.	100.	--	--	--	--
NEIL 91	8000.	0.26	0.32	0.05	33.	100.	--	--	--	--
NEWT 11	1500.	0.08	0.38	0.90	42.	100.	--	310.	35.	0.10
NEWT 12	4000.	0.93	1.56	0.0	60.	100.	--	260.	15.	1.50
NEWT 21	20000.	1.15	3.16	1.00	54.	100.	--	222.	18.	0.14
NEWT 23	900.	0.26	0.27	0.30	77.	100.	--	219.	20.	0.15
NEWT 31	37000.	6.64	5.67	15.00	60.	1000.	787.	303.	20.	0.10
NEWT 32	4000.	0.07	0.06	0.0	67.	100.	--	--	--	--
NEWT 42	3000.	0.05	0.07	0.0	86.	100.	--	--	--	--
NEWT 52	5000.	0.18	0.15	0.0	58.	1000.	--	260.	26.	0.01
NEWT 54	1200.	0.24	0.25	0.72	93.	100.	--	--	--	--
NEWT 61	12000.	1.16	2.67	6.00	55.	100.	405.	174.	6.	0.10

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
NEWT 71	3000.	0.12	0.07	3.00	36.	100.	--	196.	24.	0.28
NEWT 72	5000.	0.20	0.14	0.0	13.	100.	--	--	--	--
OAKS 21	21000.	2.26	1.89	26.40	19.	100.	--	--	--	--
OAKS 22	21000.	2.26	1.82	0.0	19.	100.	--	--	--	--
OAKS 51	6000.	0.86	4.71	11.50	0.	100.	--	--	--	--
OAKS 82	12000.	0.95	1.78	0.0	17.	100.	--	45.	--	0.50
OAKS 83	4000.	0.55	2.06	2.58	0.	100.	--	--	--	--
OTEG 11	3500.	0.56	0.35	0.32	55.	100.	--	--	--	--
OTEG 12	3000.	0.38	0.86	0.0	15.	100.	--	--	--	--
OTEG 14	2000.	0.14	0.19	0.40	26.	100.	--	--	--	--
OTEG 21	14000.	0.25	0.61	27.04	0.	100.	--	--	--	--
OTEG 33	7000.	1.00	3.57	1.86	15.	100.	--	--	--	--
OTEG 41	8000.	0.34	0.54	14.64	11.	100.	--	--	--	--
OTEG 52	30500.	1.09	1.75	0.0	21.	1000.	200.	70.	4.	0.37
OTEG 53	5000.	0.72	2.37	2.20	8.	100.	--	--	--	--
OTEG 71	7500.	0.40	0.67	11.00	31.	100.	--	--	--	--
OTEG 73	2800.	0.40	1.25	1.39	8.	100.	--	--	--	--
OTEG 81	4400.	0.32	0.50	6.40	0.	100.	--	--	--	--
OTEG 102	9000.	0.74	1.16	0.0	12.	1000.	--	--	--	--
OTEG 104	8700.	0.47	1.07	2.24	27.	100.	--	--	--	--
OTEG 141	50000.	2.69	3.27	30.00	0.	100.	--	--	--	--
OTSC 32	16500.	0.71	0.52	0.0	2.	100.	--	--	--	--
OTSC 53	3000.	0.14	0.12	0.60	45.	100.	--	--	--	--
OTSC 61	20000.	1.08	1.12	50.00	29.	100.	--	--	--	--
OTSC 102	21000.	1.51	1.89	0.0	38.	100.	--	--	--	--
OTSC 114	1000.	0.14	0.12	0.30	6.	100.	--	--	--	--
OTSC 141	13000.	1.49	1.56	21.00	24.	100.	--	--	--	--
OTSC 181	27000.	2.32	6.79	37.20	16.	100.	--	--	--	--
OTSC 222	12000.	0.86	0.81	0.0	10.	100.	--	--	--	--
OTSC 231	21000.	1.66	1.73	22.00	12.	100.	--	--	--	--
OTSC 261	12000.	0.56	1.63	13.00	14.	100.	--	--	--	--
OTSC 291	20000.	0.72	0.75	21.00	7.	100.	--	--	--	--
OTSC 321	12000.	0.86	1.08	7.80	14.	100.	--	--	--	--
OTSC 322	12000.	0.43	0.45	0.0	32.	100.	--	--	--	--
OTSC 352	10000.	0.36	0.22	0.0	8.	100.	--	--	--	--
OTSC 361	30000.	1.29	1.89	12.40	5.	100.	--	--	--	--
OTTR 01	5000.	0.54	0.90	0.60	56.	100.	--	--	27.	--
OTTR 02	5000.	0.18	0.34	0.0	6.	100.	--	--	--	--
OTTR 11	3000.	0.32	0.74	2.80	52.	8500.	480.	200.	18.	0.03
OTTR 12	2500.	0.09	0.18	0.0	32.	100.	--	--	14.	--
OTTR 21	16000.	3.73	10.35	4.80	41.	7800.	425.	200.	35.	0.06
OWEB 11	10000.	1.08	2.69	12.00	23.	100.	--	--	--	--
OWEB 21	10000.	0.25	0.84	0.40	35.	100.	--	--	--	--
OWEB 31	10000.	0.54	0.45	12.00	65.	100000.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
OWEB 32	10000.	0.54	0.67	0.0	57.	100.	--	--	--	--
OWEB 51	11000.	0.83	2.76	9.35	29.	100.	--	--	--	--
OWEB 62	8000.	0.32	0.26	0.0	15.	100.	--	--	--	--
OWEB 64	13000.	0.47	0.39	4.05	93.	100.	--	--	--	--
OWEB 91	36500.	2.75	3.73	41.00	10.	100.	--	128.	7.	0.05
OWEB 161	31500.	0.90	1.51	29.60	2.	100.	--	--	--	--
OWEB 191	5000.	0.43	0.81	4.20	49.	100.	--	--	--	--
OWEB 192	7000.	0.50	0.47	0.0	16.	100.	--	--	--	--
OWEB 193	13500.	1.69	4.24	4.80	79.	8000.	--	--	--	--
OWEB 211	19000.	0.34	0.21	11.70	26.	100.	--	--	--	--
OWGO 11	7000.	0.55	1.96	14.00	24.	100.	--	--	--	--
OWGO 22	13000.	1.40	2.04	0.0	23.	100.	--	--	--	--
OWGO 31	17500.	1.88	2.16	29.40	19.	100.	--	--	--	--
OWGO 42	4500.	0.48	0.71	0.0	29.	100.	--	--	--	--
OWWB 21	24000.	1.12	1.63	20.00	5.	100.	--	--	--	--
OWWB 71	34000.	1.34	2.80	24.85	8.	100.	--	--	--	--
OWWB 121	23000.	0.50	0.77	14.10	17.	100.	--	--	--	--
OWWB 161	13000.	1.31	1.91	6.00	59.	100.	--	--	--	--
PAGE 21	21000.	0.75	0.24	4.40	2.	100.	--	--	--	--
PAGE 02	5500.	0.36	0.15	0.0	0.	100.	--	--	4.	--
PAYN 11	7000.	0.93	4.31	7.38	33.	100.	--	--	--	--
PAYN 31	24000.	3.44	5.03	10.80	31.	1000.	--	--	--	--
PAYN 34	16000.	0.86	1.29	7.95	15.	100.	--	--	--	--
PAYN 52	42000.	2.71	2.67	0.0	9.	100.	--	--	--	--
PAYN 64	10000.	1.79	2.33	3.60	43.	100.	--	--	--	--
PAYN 71	14000.	3.26	12.44	6.00	31.	100.	--	--	--	--
PONY 21	22000.	1.50	3.91	4.70	10.	100.	--	--	--	--
POST 11	4500.	0.10	0.04	3.60	7.	100.	--	--	--	--
POST 41	19000.	0.82	0.31	11.70	32.	100.	--	--	--	--
POST 42	19000.	0.41	0.34	0.0	31.	100.	--	--	--	--
POST 91	34000.	2.20	3.20	9.30	22.	100.	--	120.	10.	0.20
POST 122	5000.	0.13	0.10	0.0	94.	100.	--	--	--	--
SANG 71	75000.	12.11	60.53	37.60	5.	100.	--	--	--	--
SCHE 12	5300.	0.44	0.85	0.0	29.	100.	--	--	--	--
SCHE 21	12700.	1.09	6.03	13.20	16.	100.	--	--	--	--
SCHE 61	25800.	1.85	0.77	21.21	12.	100.	--	--	--	--
SCHE 62	25800.	1.39	1.45	0.0	9.	100.	148.	62.	3.	0.21
SCHE 141	58000.	2.50	2.08	26.80	1.	100.	--	--	--	--
SEEL 11	10000.	0.72	0.33	2.80	83.	100.	--	--	--	--
SEEL 12	7000.	0.50	1.26	0.0	51.	100.	--	--	--	--
SEEL 14	800.	0.13	0.15	0.0	8.	100.	--	--	--	--
SEEL 31	33000.	1.78	4.81	35.00	40.	100.	--	--	--	--
SEEL 41	10000.	0.43	0.13	11.20	64.	100.	--	--	--	--
SEEL 42	10000.	0.43	0.63	0.0	55.	100.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
SEEL 43	800.	0.27	0.12	0.0	92.	100.	--	--	--	--
SEEL 54	600.	0.17	3.81	0.20	0.	100.	--	--	--	--
SOBR 12	13000.	0.51	0.64	0.0	11.	100.	--	--	--	--
SOBR 31	11000.	0.39	0.58	3.30	14.	100.	--	--	--	--
SUSQ 13	1500.	0.62	0.77	0.90	95.	100.	--	--	--	--
SUSQ 23	1500.	0.56	1.41	18.40	99.	100.	--	--	--	--
SUSQ 22	9500.	0.24	0.80	0.0	50.	100.	--	--	--	--
SUSQ 44	1800.	0.39	0.57	0.0	41.	100.	--	--	--	--
SUSQ 52	9500.	0.68	0.43	0.0	25.	100.	--	--	--	--
SUSQ 61	30000.	2.15	1.80	270.00	60.	100.	--	--	--	--
SUSQ 63	1200.	0.09	0.07	0.60	19.	100.	--	--	--	--
SUSQ 81	23000.	1.49	3.41	66.00	49.	100.	--	154.	25.	0.54
SUSQ 93	1800.	0.48	0.71	42.00	88.	100.	--	--	--	--
SUSQ 104	9000.	0.65	0.81	9.00	82.	100.	--	104.	20.	0.12
SUSQ 112	8500.	0.21	0.27	0.0	40.	100.	--	--	--	--
SUSQ 121	15000.	1.18	0.99	180.00	61.	100.	--	--	--	--
SUSQ 124	17000.	1.22	0.38	0.80	55.	100.	--	--	--	--
SUSQ 122	15000.	1.29	0.94	0.0	19.	1000.	--	171.	--	0.03
SUSQ 134	1500.	0.24	0.68	0.0	85.	100.	--	--	--	--
SUSQ 141	12000.	1.29	1.62	132.00	54.	100.	--	--	--	--
SUSQ 144	900.	0.24	0.25	0.36	62.	100.	--	--	--	--
SUSQ 154	2000.	0.54	1.23	0.50	94.	100.	--	--	--	--
SUSQ 171	8500.	0.24	0.36	46.75	54.	100.	--	--	--	--
SUSQ 181	8500.	1.83	6.49	49.50	46.	100000.	--	128.	24.	0.04
SUSQ 201	9000.	0.48	1.48	108.00	23.	100.	--	--	--	--
SUSQ 221	14000.	2.26	7.87	169.00	15.	100.	--	--	--	--
SUSQ 241	18000.	1.23	0.74	216.00	55.	100.	--	--	--	--
SUSQ 252	5000.	0.23	0.19	0.0	50.	100.	--	--	--	--
SUSQ 262	2000.	0.14	0.12	0.0	27.	100.	--	--	--	--
SUSQ 264	11000.	0.63	0.72	0.0	63.	100.	--	--	--	--
SUSQ 271	15500.	1.06	2.29	145.00	22.	100.	--	130.	45.	0.08
SUSQ 282	5000.	0.36	0.37	0.0	21.	100.	--	120.	--	--
SUSQ 291	2500.	0.07	0.25	0.0	43.	100.	--	--	--	--
SUSQ 292	10000.	0.36	0.34	0.0	36.	100.	--	60.	11.	0.04
SUSQ 301	5500.	0.28	0.39	13.00	76.	100.	--	108.	5.	0.06
SUSQ 302	6500.	0.35	0.66	0.0	59.	100.	--	310.	52.	0.06
SUSQ 304	600.	0.09	0.07	0.0	54.	100.	--	--	--	--
SUSQ 311	14500.	0.78	2.25	125.00	51.	100.	--	--	--	--
SUSQ 312	2700.	0.07	0.11	0.0	68.	100.	--	--	--	--
SUSQ 314	8000.	0.32	0.32	4.75	70.	100.	--	--	--	--
SUSQ 322	3000.	0.16	0.27	0.0	23.	100.	--	--	--	--
SUSQ 331	5000.	0.29	1.10	50.00	21.	100.	--	171.	--	--
SUSQ 332	8000.	0.34	0.86	0.0	41.	100.	--	210.	19.	0.15
SUSQ 341	8500.	0.58	1.84	85.00	51.	100.	--	250.	7.	0.03

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
SUSQ 342	3000.	0.11	0.13	0.0	24.	100.	--	176.	12.	0.02
SUSQ 351	11000.	0.39	0.33	0.12	61.	100.	--	--	--	--
SUSQ 352	2700.	0.07	0.16	0.0	60.	6000.	--	156.	11.	0.28
SUSQ 354	2000.	0.27	0.34	0.0	61.	100.	--	--	--	--
SUSQ 361	7000.	0.55	1.84	48.00	42.	5000.	--	275.	25.	0.20
SUSQ 362	2000.	0.06	0.07	0.0	42.	100.	--	170.	--	0.40
SUSQ 363	1500.	0.19	0.29	0.40	82.	5000.	--	154.	20.	--
SUSQ 371	7000.	0.40	0.28	20.00	59.	2000.	--	320.	28.	--
SUSQ 372	10000.	0.39	0.74	0.0	44.	7000.	630.	300.	38.	0.10
SUSQ 373	7000.	0.40	0.25	1.30	51.	100.	--	--	--	--
SUSQ 381	9000.	0.39	1.01	0.0	45.	3000.	830.	330.	40.	0.50
SUSQ 391	7000.	0.25	0.84	9.00	63.	2000.	--	--	--	--
SUSQ 392	6000.	0.28	0.82	0.0	62.	4000.	550.	240.	30.	0.40
SUSQ 393	1300.	0.10	0.12	9.60	38.	100000.	--	156.	14.	--
SUSQ 401	9000.	0.65	0.61	48.00	41.	100.	--	325.	--	--
SUSQ 411	16000.	0.75	1.40	82.40	33.	100.	--	150.	20.	--
SUSQ 431	3000.	0.27	0.22	18.00	45.	100.	--	--	--	--
SUSQ 432	3000.	0.22	0.13	0.0	35.	100.	700.	300.	82.	5.30
SUSQ 433	1700.	0.06	0.04	0.0	25.	100.	--	--	--	--
SUSQ 441	8000.	0.69	1.29	51.00	8.	100.	--	70.	10.	0.11
SUSQ 443	3300.	0.09	0.09	0.53	52.	100.	--	--	--	--
SUSQ 461	9000.	1.13	0.71	45.00	28.	100.	--	--	--	--
SUSQ 471	2000.	0.06	0.10	12.00	57.	100.	--	48.	9.	0.16
SUSQ 482	5000.	0.29	0.48	0.0	4.	100.	--	--	--	--
SUSQ 501	26500.	2.19	1.37	228.00	10.	100.	--	--	--	--
SUSQ 692	13500.	0.87	2.09	0.0	24.	100.	--	--	--	--
SUSQ 714	800.	0.10	0.14	0.05	39.	100.	--	--	--	--
SUSQ 722	4500.	0.11	0.15	0.0	8.	100.	280.	114.	15.	0.03
SUSQ 733	1500.	0.16	0.30	0.20	74.	100.	--	--	--	--
SUSQ 742	8000.	0.43	0.54	0.0	33.	100.	--	--	--	--
SUSQ 771	12000.	0.52	0.86	87.50	11.	100.	--	--	--	--
SUSQ 792	7500.	0.32	0.54	0.0	28.	100.	--	--	--	--
SUSQ 832	8000.	0.14	0.30	0.0	12.	100.	--	--	--	--
SUSQ 842	12000.	0.65	1.75	0.0	18.	100.	--	--	--	--
SUSQ 872	13000.	1.63	1.70	0.0	43.	100.	--	--	--	--
SUSQ 892	12000.	0.99	2.06	0.0	35.	100.	--	--	--	--
SUSQ 922	10000.	1.79	2.99	0.0	17.	100.	--	--	--	--
SUSQ 934	12500.	0.54	1.35	10.50	9.	100.	--	--	--	--
SUSQ 942	18500.	1.99	5.81	0.0	20.	100.	--	--	--	--
SUSQ 941	5000.	0.22	0.43	35.00	0.	1000.	--	6.	0.	0.0
SUSQ 951	7000.	0.63	0.26	1.00	50.	100.	--	--	--	--
SUSQ 963	3500.	0.50	2.36	1.05	2.	100.	--	--	--	--
SUSQ 973	4500.	0.32	1.65	1.95	3.	100.	--	--	--	--
SUSQ 981	9000.	0.39	0.57	70.00	0.	100.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
SUSQ 992	12000.	1.29	2.15	0.0	0.	1000.	--	--	--	--
SUSQ1011	10000.	1.08	2.35	100.00	0.	100.	--	75.	2.	0.03
SUSQ1032	10500.	1.13	1.89	0.0	36.	100.	--	230.	18.	0.30
SUSQ1044	7000.	0.28	0.80	3.00	7.	100.	--	--	--	--
SUSQ1053	3000.	0.43	0.90	0.90	21.	100.	--	176.	7.	--
SUSQ1071	35000.	2.51	5.97	140.60	5.	100.	--	--	--	--
SUSQ1082	17000.	1.83	5.72	0.0	8.	1000.	--	--	--	--
SUSQ1084	8000.	0.43	1.20	6.65	22.	100.	--	--	--	--
SUSQ1101	5000.	0.09	0.13	18.00	46.	100.	--	--	--	--
SUSQ1123	4500.	0.65	3.66	2.00	3.	100.	--	--	--	--
SUSQ1143	7000.	1.00	6.07	5.00	3.	100.	--	--	--	--
SUSQ1162	60000.	6.46	10.77	0.0	14.	100.	168.	92.	3.	0.15
SUSQ1201	30000.	4.30	3.14	122.10	5.	100.	--	--	--	--
SUSQ1223	3500.	0.50	2.41	0.64	23.	100.	--	--	--	--
SUSQ1251	25000.	2.24	8.79	111.44	0.	1000.	--	--	--	--
SUSQ1252	5400.	0.52	0.65	0.0	10.	100.	--	--	--	--
SUSQ1281	8000.	0.72	0.67	12.00	8.	1000.	--	--	--	--
SUSQ1301	14000.	1.26	0.79	320.00	22.	100.	--	--	--	--
SUSQ1302	25000.	2.24	11.69	0.0	14.	100.	--	--	--	--
SUSQ1313	3600.	0.15	0.89	1.80	4.	100.	--	--	--	--
SUSQ1331	12000.	1.29	11.94	45.50	0.	100.	--	--	--	--
SUSQ1361	4800.	0.34	0.24	0.0	71.	100.	--	--	--	--
SUSQ1372	4200.	0.30	1.26	0.0	35.	100.	--	--	--	--
SUSQ1373	4200.	0.30	1.26	2.55	4.	100.	--	--	--	--
SUSQ1401	7000.	0.75	6.45	28.14	0.	100.	--	--	--	--
SUSQ1414	7000.	0.38	0.62	3.12	0.	100.	--	--	--	--
SUSQ1421	2500.	0.15	0.11	0.0	100.	100.	--	--	--	--
SUSQ1423	2500.	0.18	0.71	0.72	3.	100.	--	--	--	--
SUSQ1432	27000.	2.13	2.22	0.0	14.	1000.	--	--	--	--
SUSQ1441	11000.	0.30	0.43	20.60	3.	100.	--	--	--	--
TIOG 12	10000.	0.65	2.63	0.0	58.	100.	--	164.	7.	0.03
TIOG 24	2000.	1.87	1.95	0.0	97.	100.	393.	175.	15.	0.03
TIOG 31	23000.	2.15	6.58	135.00	48.	100.	--	110.	9.	0.14
TIOG 81	39000.	2.52	2.36	129.00	33.	100.	--	--	--	--
TIOG 91	26000.	0.65	1.63	21.00	42.	100.	--	--	--	--
TIOG 92	33000.	1.89	1.97	0.0	52.	100.	--	--	--	--
TIOU 21	21000.	0.60	0.34	92.40	4.	100.	--	--	--	--
TIOU 44	23000.	0.66	0.41	4.80	77.	100.	--	--	--	--
TIOU 71	37000.	2.12	1.42	152.00	14.	100.	--	208.	6.	0.04
TIOU 151	40000.	1.87	1.56	124.50	8.	100.	--	158.	58.	0.08
TIOU 241	48000.	1.38	1.67	128.70	4.	100.	--	--	--	--
TIOU 301	14000.	1.26	1.31	30.80	22.	100.	--	--	--	--
TIOU 322	3500.	0.50	1.26	0.0	35.	100.	--	160.	3.	0.20
TIOU 331	12000.	1.64	2.39	6.00	73.	100.	--	--	22.	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter) Hardness (as $CaCO_3$)	Chloride	Iron
TROU 11	5000.	0.22	0.45	2.60	19.	100.	--	--	--	--
TROU 21	11000.	0.39	0.41	4.56	13.	100.	--	--	--	--
TROU 51	20000.	0.43	0.18	6.30	5.	100.	--	--	--	--
TWEL 91	8000.	0.63	1.18	1.40	29.	100.	--	--	--	--
TWEL 31	33000.	0.83	1.30	10.50	2.	100.	--	--	--	--
UNAD 22	7000.	0.25	0.21	0.0	24.	1000.	184.	84.	4.	0.06
UNAD 23	1500.	0.39	0.88	1.12	0.	100.	--	--	--	--
UNAD 34	3000.	0.54	0.88	1.03	21.	100.	--	--	--	--
UNAD 41	23000.	2.06	0.86	52.80	25.	100.	--	--	--	--
UNAD 52	23000.	2.06	2.63	0.0	25.	100.	89.	35.	3.	1.20
UNAD 63	2500.	0.63	1.51	1.28	3.	100.	--	--	--	--
UNAD 81	9000.	0.74	0.30	0.30	60.	100.	--	--	--	--
UNAD 101	13000.	0.79	3.73	33.80	0.	100.	--	--	--	--
UNAD 134	1000.	0.07	0.20	0.24	4.	100.	--	--	--	--
UNAD 141	16900.	1.82	1.71	43.20	17.	100.	--	--	--	--
UNAD 142	22000.	2.37	9.55	0.0	14.	100.	--	--	--	--
UNAD 163	8000.	1.00	5.84	3.39	14.	100.	--	--	--	--
UNAD 202	41200.	2.96	2.93	0.0	2.	100.	--	--	--	--
UNAD 221	23800.	2.56	1.03	72.00	5.	100.	--	--	--	--
UNAD 241	6000.	0.82	2.50	15.20	0.	1000.	--	--	--	--
UNAD 263	3000.	0.22	0.81	1.92	20.	100.	--	--	--	--
UNAD 272	26400.	2.08	4.74	0.0	15.	100.	--	--	--	--
UNAD 281	17400.	1.62	0.81	36.00	14.	100.	--	--	--	--
UNAD 291	5200.	0.47	0.43	10.80	32.	100.	--	165.	2.	0.06
UNAD 301	12200.	1.53	6.17	23.40	4.	100.	--	--	--	--
UNAD 313	4000.	0.33	1.29	0.96	23.	100.	--	--	--	--
UNAD 321	4000.	0.17	0.12	2.19	18.	100.	--	--	--	--
UNAD 332	12000.	1.21	6.79	0.0	0.	100.	--	--	--	--
UNAD 351	8400.	0.87	0.88	19.20	15.	100.	--	--	--	--
UNAD 362	13200.	1.42	4.15	0.0	17.	100.	--	--	--	--
UNAD 391	6700.	0.29	0.17	10.20	0.	100.	--	--	--	--
UNAD 422	37500.	8.07	4.03	0.0	14.	1000.	--	--	--	--
UNAD 461	12000.	2.15	17.51	10.00	2.	100.	--	255.	--	1.80
UNWB 12	9000.	1.13	0.69	0.0	14.	100.	--	--	--	--
UNWB 21	7500.	1.61	2.10	4.00	33.	1000.	--	--	--	--
UNWB 41	15600.	3.36	8.05	3.36	27.	100.	--	--	--	--
VNET 12	5500.	0.18	0.19	0.0	14.	100.	--	--	--	--
VNET 11	4000.	0.29	0.48	0.40	43.	100.	--	410.	219.	5.60
WHAR 21	18000.	2.20	20.00	42.00	0.	100.	--	--	--	--
WHAR 54	3500.	0.33	1.64	0.86	7.	100.	--	--	--	--
WHAR 62	35000.	4.14	3.35	0.0	22.	100.	--	--	--	--
WHAR 63	4000.	0.36	1.47	4.08	6.	100.	--	--	--	--
WHAR 91	7800.	0.56	0.47	8.96	40.	100.	--	--	--	--
WHAR 93	3500.	0.38	1.29	1.05	22.	100.	--	--	--	--

Table 4.--AQUILIST tabulation of aquifers (continued)

Aquifer	Length (feet)	Area (square miles)	Volume of water in storage (billions of gallons)	Potential induced infiltration (millions of gallons per day)	Percentage of side area bordered by sand and gravel	Hydraulic conductivity, horizontal (gallons per day per foot squared)	Specific conductance (micromhos per centimeter at 25°C)	Chemical data (milligrams per liter)		
								Hardness (as $CaCO_3$)	Chloride	Iron
WHAR 102	9000.	0.87	0.53	0.0	7.	100.	--	--	--	--
WHAR 111	7000.	0.75	1.26	5.52	0.	100.	--	--	--	--
WHAR 133	3000.	0.26	0.67	1.08	6.	100.	--	--	--	--
WHAR 144	3000.	0.32	0.83	1.06	5.	100.	--	--	--	--
WHAR 152	37000.	2.79	2.27	0.0	31.	100.	--	--	--	--
WHAR 163	2200.	0.47	1.18	1.35	3.	100.	--	--	--	--
WHAR 164	2100.	0.34	0.81	1.04	3.	100.	--	--	--	--
WHAR 193	2800.	0.15	0.34	1.43	30.	100.	--	--	--	--
WILL 04	700.	0.23	0.49	0.24	97.	100.	--	--	--	--
WILL 14	17000.	0.43	0.49	3.60	86.	100.	--	--	--	--
WILL 22	24000.	1.29	1.62	0.0	21.	100.	--	--	--	--
WILL 31	32000.	1.84	2.30	13.20	24.	100.	--	--	--	--
WILL 71	10000.	1.08	1.57	1.00	35.	100.	--	--	--	--
WTIC 11	6000.	0.19	0.10	1.95	22.	100.	--	--	--	--
WTIC 41	24000.	1.89	1.58	5.00	12.	100.	--	--	--	--
WTIC 44	8000.	0.43	0.27	1.70	68.	100.	--	--	--	--
WTIO 11	7500.	1.13	2.10	9.60	36.	100.	--	--	18.	--
WTIO 21	5000.	0.36	0.52	5.00	64.	100.	740.	340.	90.	--
WTIO 23	2500.	0.45	1.26	1.25	88.	100.	--	186.	8.	0.02
WTIO 33	29000.	1.77	6.64	8.10	94.	100.	--	--	--	--
WTIO 51	27000.	3.87	7.68	17.40	13.	1000.	500.	235.	40.	--
WTIO 83	15000.	1.35	1.62	0.0	86.	100.	--	--	--	--
WTIO 91	18000.	4.00	9.18	7.60	42.	1000.	400.	225.	9.	--
WTIO 111	13000.	4.20	10.50	0.0	45.	100.	--	--	--	--
WTIO 124	4500.	0.16	0.20	0.35	41.	100.	--	--	--	--